POLARAD

PROVEN RELIABILITY

HANDBOOK
OF
OPERATING INSTRUCTIONS

POLARAD ELECTRONICS CORPORATION, 43-20 34th STREET, LONG ISLAND CITY 1, N.Y.

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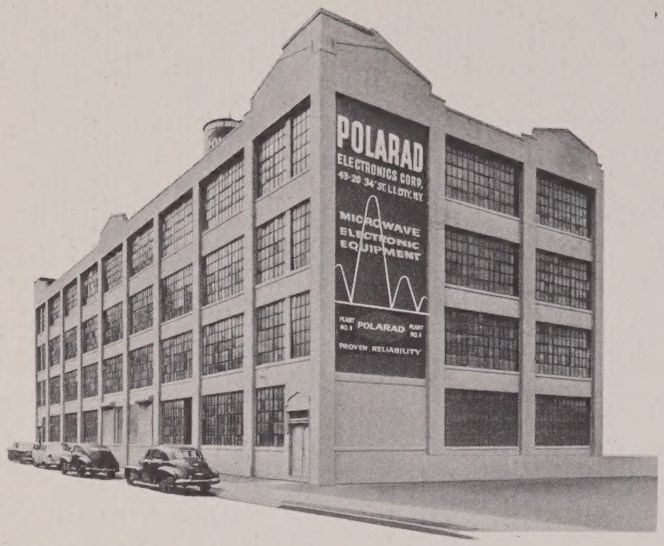

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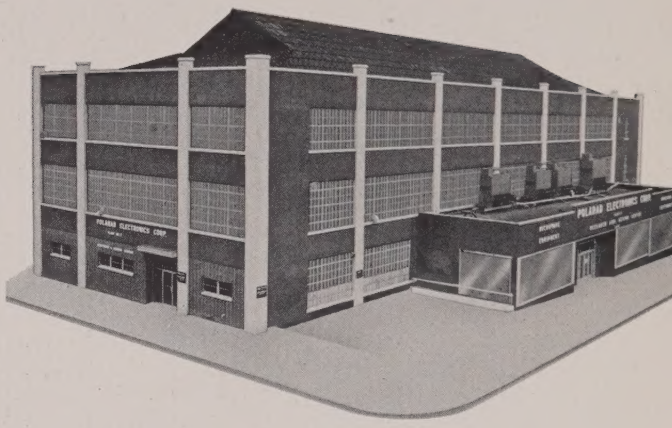

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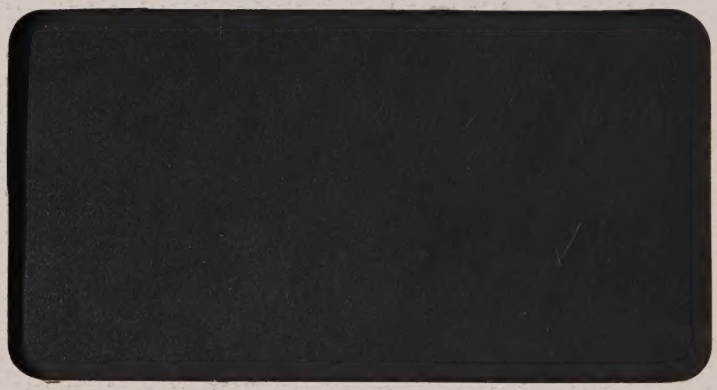

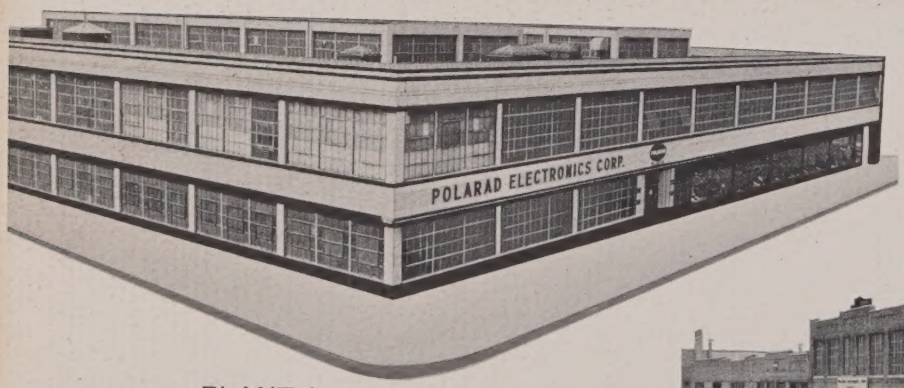

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POLARAD

PROVEN RELIABILITY

INSTRUCTION MANUAL

PULSE JITTER TESTER
MODEL PJ-1

(Serial No. 182 and up)

POLARAD ELECTRONICS CORPORATION

43-20 34th STREET • LONG ISLAND CITY 1 • NEW YORK, N. Y.

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POLARAD

PROVEN RELIABILITY

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WARNING

APPLICATION OF POWER TO THIS EQUIPMENT RESULTS IN VERY HIGH VOLTAGES WHICH CAN BE FATAL. OBSERVE ALL SAFETY PRECAUTIONS AT ALL TIMES.

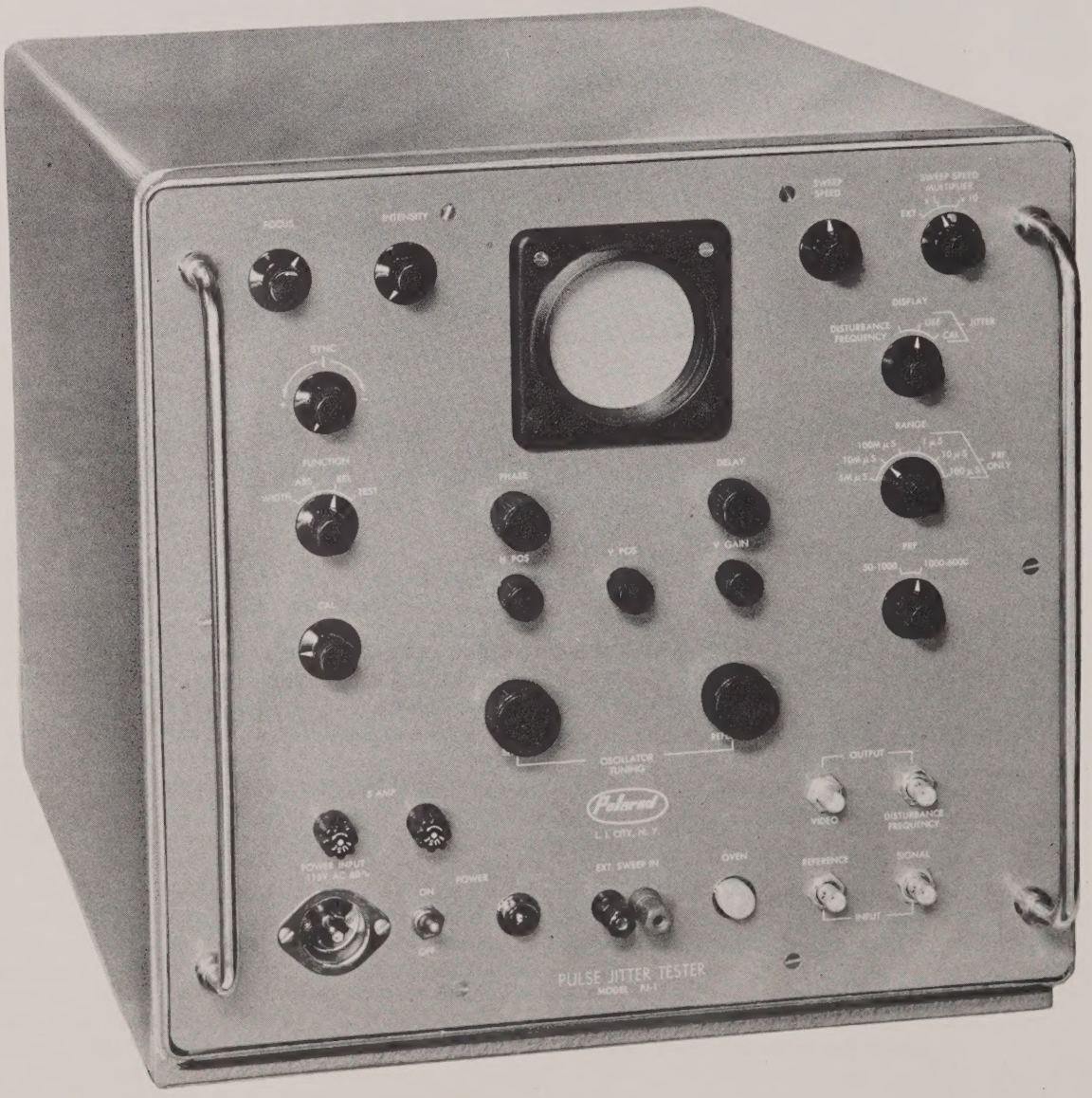


Figure 1-1. The Polarad Model PJ-1 Pulse Jitter Tester

MODEL PJ-1
PULSE JITTER TESTER

SECTION 1
GENERAL DESCRIPTION

1-1. SCOPE OF HANDBOOK

The purpose of this handbook is to present the description, the principles of operation, and instructions for operating and maintaining the Polarad Model PJ-1 Pulse Jitter Tester. A description of the physical and electrical characteristics of the equipment, as well as a detailed explanation of its theory of operation, is included in sections 1 and 2 of this handbook. Procedures for operation are covered in section 3, adjustments and maintenance procedures in section 4, a detailed equipment tube complement in section 5, overall schematics in section 6, and a list of replaceable parts in section 7 of the handbook.

1-2. PURPOSE OF EQUIPMENT

The Polarad Model PJ-1 Pulse Jitter Tester is an instrument designed to measure and display, on a self-contained oscilloscope, pulse width jitter, relative jitter, and absolute jitter. In addition, the instrument displays the jitter envelope to permit analysis of frequency component waveforms, and other characteristics. This instrument is of great value in performing the above measurements on rate generators, pulse width modulators, computers, encoding devices, pulse generators, precision time generators, MTI Radar systems, and other similar equipments.

1-3. BASIC DEFINITIONS

a. Pulse Width Jitter. Pulse width jitter is defined as the peak-to-peak time deviation between the leading and trailing edges of a recurrent pulse.

b. Relative Jitter. Relative jitter is defined as the peak-to-peak time deviation of the leading edge of one pulse, with respect to the leading edge of a reference pulse.

c. Absolute Jitter. Absolute jitter is defined as the peak-to-peak time deviation of the period of a pulse train, with respect to the time representing the nominal period, as determined by the pulse repetition rate.

1-4. DESCRIPTION

The Polarad Model PJ-1 Pulse Jitter Tester is a portable, compact, self-contained instrument. The instrument displays both the magnitude and waveform of the jitter under measurement. An EXT. SWEEP input is provided to facilitate determination of the jitter frequency. The control panel is provided with two handles, which facilitate carrying the instrument, or removal of the chassis from the case for maintenance. All operating and adjustment controls, as well as all indicating lamps and protective fuses, are mounted on the front panel. Also mounted on the front panel are two BNC connectors, marked VIDEO OUTPUT and DISTURBANCE FREQUENCY OUTPUT, and two additional connectors marked REFERENCE INPUT and SIGNAL INPUT. The two output connectors permit measurement or display on an external oscilloscope of the video and disturbance frequencies. The two input connectors permit application of an input signal and a reference signal to the Pulse Jitter Tester. Power input to the instrument is applied via a detachable power cable assembly which mates with the power receptacle mounted in the lower left section of the front panel. Two front panel jacks, EXT. SWEEP IN, are provided, so that an audio oscillator signal can be applied to the horizontal amplifiers. The resultant Lissajous pattern permits disturbance frequency measurement.

1-5. GENERAL APPLICATIONS

The Polarad Model PJ-1 Pulse Jitter Tester is ideally suited for determination of pulse jitter measurements in a wide variety of equipments, both test and experimental. The jitter characteristics of pulses, video amplifiers, wave-shaping and pulse-forming circuits, as well as signal generators and signal sources, can be measured with this instrument. In the measurement of jitter present in the output signals of signal generators and signal sources, only pulses may be applied to the input of the Pulse Jitter Tester. Therefore, the output signals of these equipments must be applied to the Pulse Jitter Tester through suitable waveform generators or pulse-shaping networks.

1-6. TECHNICAL CHARACTERISTICS

a. Input Signal Requirements:	
Pulse Width	0.2 to 10.0 microseconds.
Repetition Rate	50 to 6,000 pps.
Amplitude	5 to 50 volts, peak-to-peak.
Polarity	Positive or negative.
Input Impedance	82,000 ohms shunted by 25 micromicrofarads.
Maximum delay between reference and signal pulse	50 microseconds.
b. Jitter Measurements:	
Residual Jitter	Less than 0.5 millimicrosecond.
Width or Relative Jitter	5, 10, 100 millimicroseconds full scale.
Small Absolute Jitter	5, 10, 100 millimicroseconds full scale.
Large Absolute Jitter	1, 10, 100 microseconds full scale.
c. Usable Horizontal Frequency Range	15 cycles to 25 kc.
d. Power Input	115 volts ±10%, 50 to 420 cps, 400 watts.
e. Dimensions	17" wide by 17-1/2" high by 19-1/4" deep.
f. Weight	60 pounds.
g. Outputs Provided for	(1) External oscilloscope; (2) Recorder (±5 ma into 100 ohms) for disturbance frequency.
h. Accessory Equipment Supplied	(1) One 8-ft power cord assembly, with male plug on one end, and twistlock socket at the other end. (2) Two 8-ft video cable assemblies, with BNC to BNC connectors on each end. (3) Three test cables.

SECTION 2
THEORY OF OPERATION

2-1. CONDENSED PRINCIPLES OF OPERATION

a. General. The Model PJ-1 Pulse Jitter Tester includes circuitry to permit the measurement of repetition rate jitter, as well as width or relative jitter. The unit displays both the magnitude of the jitter and the waveform of the jitter modulation on a cathode-ray tube. An EXT. SWEEP IN is provided to facilitate determination of the jitter frequency.

b. Purpose. The Polarad Model PJ-1 Pulse Jitter Tester is designed to detect the time jitter (or variation) of a pulse, by converting the time position variations of the pulse into the phase angle of a 5 mc rf pulse. Any variation of the time position of the input pulse becomes a phase variation of the rf pulse. The reference used is dependent upon the type of jitter measurement desired, that is, relative, absolute, or width. (See figure 2-1.)

c. Repetition Rate Jitter. When measuring repetition rate jitter, a 5 megacycle oscillator is gated on with the leading edge of the pulse under observation. The output of this oscillator is compared with a stable 5 megacycle crystal-controlled oscillator in a phase detector. The output of the phase detector is a train of pulses, which have a peak-to-peak maximum output voltage corresponding to a phase difference of 180°, equivalent to 100 millimicroseconds at 5 megacycles. By using a calibrated attenuator to divide the pulse amplitude of the phase detector output by known factors, and displaying these pulses on an oscilloscope, successive scale factors of 1.0, 0.1, and 0.05 are provided. The scale factors correspond to 100 millimicroseconds, 10 millimicroseconds, and 5 millimicroseconds. In order to maintain the average phase at zero, the output of the phase detector is passed through a low-pass filter to drive a reactance tube which adjusts the frequency of the free-running 5 megacycle oscillator, compensating for long-time repetition rate drift.

d. Relative Jitter. When measuring relative jitter, the two input pulses under measurement are applied to the instrument. The leading edge of one input pulse triggers one 5 megacycle oscillator into operation; the leading

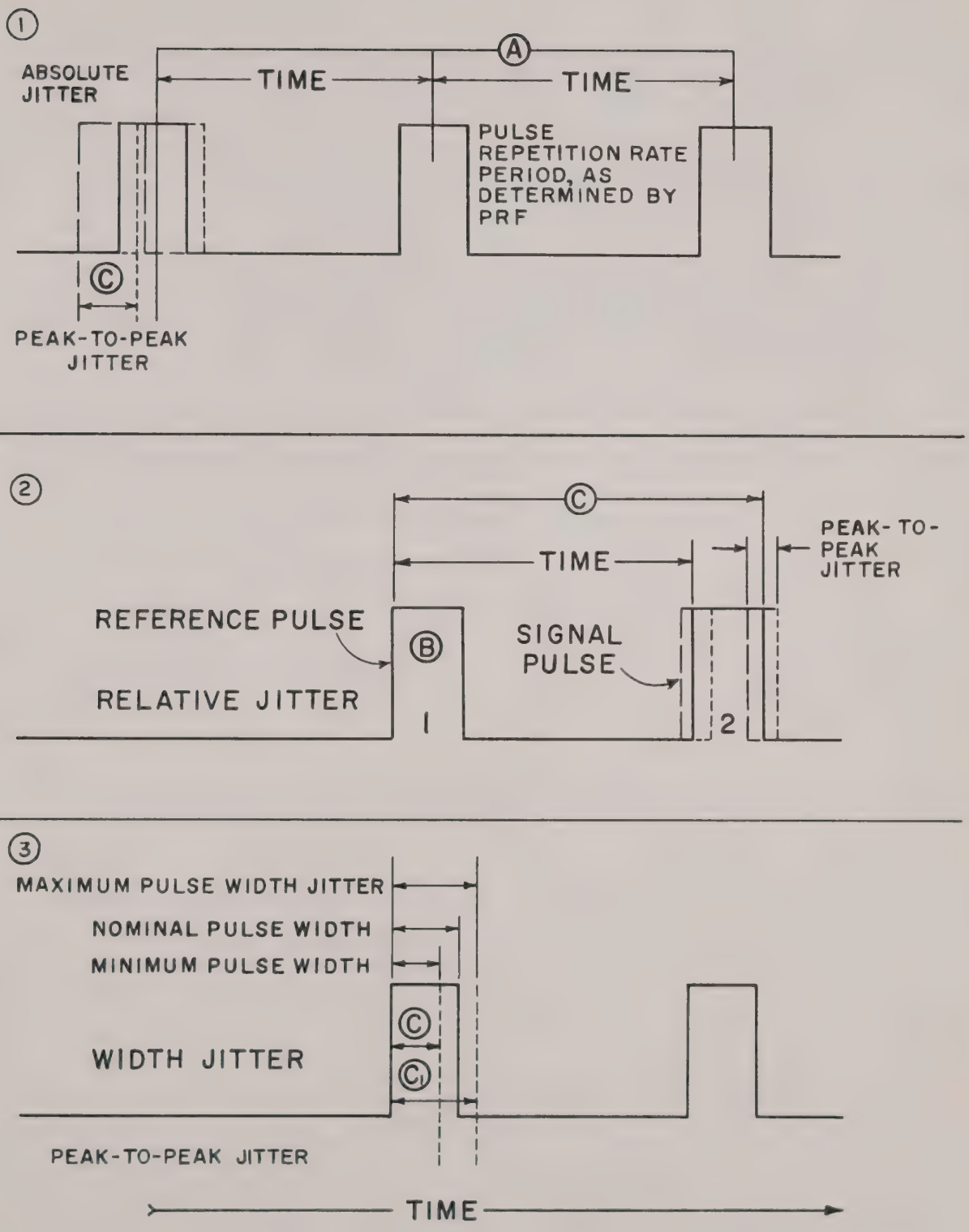


Figure 2-1. Jitter Waveform Time Relationships, Master Chart

edge of the second input pulse triggers a second 5 megacycle oscillator into operation. The outputs of the two 5 megacycle oscillators are compared in the phase detector, and the resultant output signal is displayed on the oscilloscope. Manual tuning of the two oscillator stages is provided to obtain a zero beat.

e. Width Jitter. When measuring width jitter, the pulse under measurement is applied to the input of the instrument. The leading edge of the pulse under measurement triggers one of the 5 megacycle oscillators into operation; the trailing edge of the pulse under measurement triggers the second 5 megacycle oscillator into operation. Readings are made in the same manner as for relative jitter.

f. Boxcar Circuit. The envelope of the jitter time modulation is presented on the oscilloscope display as a voltage which is obtained through a boxcar holding circuit. This circuit, operating on the output of the phase detector, generates a voltage which is passed through a low-pass filter, thereby eliminating transients. When displaying the jitter envelope, the oscilloscope horizontal sweep is continuously adjustable, and can be synchronized with the signal frequency. Provision is made to introduce external sweep voltages, for frequency calibration by means of Lissajous figures.

g. Signal Channels. The instrument contains two identical signal channels. One channel is used for the signal whose jitter is to be measured; the second channel is used to develop a reference signal. The first channel is in operation in all types of measurements, but the second (reference channel) is used in certain applications only, as listed below:

(1) In relative jitter measurements, both the signal and reference channels are in operation.

(2) In absolute jitter measurements, only the signal channel is in operation.

(3) In width jitter measurements, the signal channel and a particular portion of the reference channel are in operation.

For a detailed discussion of the various circuits and channels, refer to the block and simplified schematic circuit diagrams in this section of the handbook and to the overall schematic diagrams located in section 6.

2-2. RELATIVE JITTER MEASUREMENT, BLOCK DIAGRAM DESCRIPTION (See figures 2-2 and 2-7.)

a. Restatement of Definition. Relative jitter is defined as the peak-to-peak time deviation of the leading edge of one pulse, with respect to the leading edge of a reference pulse. The following discussion is based upon the circuits in operation for this measurement, as represented in figure 2-7.

b. The signal under measurement is applied to cathode follower and phase inverter V401. The output of this stage, always of negative polarity, is coupled to the slicer, cathode follower, peak detector, and feedback amplifier networks (CR401, CR402, V404, and V405). These networks always develop an output signal which is 50% of the level of the applied input signal. This signal is coupled to trigger amplifier V402 and cathode follower V403A. Upon receipt of a trigger, trigger amplifier V101A enables gated multivibrator V102, which generates a pulse of approximately 100 microseconds duration. The pulse from V102 is applied to both gating cathode follower V103A and cathode follower sweep gate V101B. The gate signal from V101B is coupled to sweep phantastron tube V311, so that the horizontal sweep will start at the same time that the video information is applied to the vertical deflection plates of the CRT.

c. V103A, which is connected across gated 5 mc oscillator V103B, constitutes a low-impedance shunt across the resonant network of V103B. The negative pulse from V102 drives V103A to cutoff, removing the shunt from V103B, and thus permits V103B to oscillate for a period of time represented by the duration of the pulse developed by gated multivibrator V102. The signal from V103B is applied to phase inverter V104. The PHASE control of this stage permits setting the average phase of the comparison signals to zero. V105 amplifies the 5 mc oscillator signal, and its output is coupled to the 5 mc signal driver V106. This stage amplifies the signal to a level adequate for driving the control grid of phase detector V107.

d. The reference signal input is applied to the reference channel circuits, which are identical to the signal input channel circuits (except that the reference channel has no cathode follower sweep gate stage). This channel includes the reference circuits from V406 through V203B. The 5 mc pulse from V203B is amplified by 5 mc

reference driver V204, which drives the suppressor grid (functioning as a control grid) of phase detector V107. The output of V107 is controlled by the simultaneous application of signals from both the signal channel and the reference channel. Any phase difference between the outputs of the two channels will result in a linear change in the signal from V107. Thus, the pulse width from V107 is proportional to any phase difference between the signal pulse and the reference pulse.

e. The output of phase detector V107 is a train of pulses which has a peak-to-peak amplitude corresponding to a phase difference of 180 degrees, equivalent to 100 millimicroseconds. Cathode follower V108 couples the video information from V107 to both a calibrated attenuator, and to cathode follower V108B. The resultant signal from V108B is an afc control voltage, which is applied only when making absolute jitter measurement.

f. The attenuator is used to divide the phase detector output by known factors, providing progressive scale factors of 1, 0.1, and 0.05, corresponding to 100, 10, and 5 millimicroseconds. The attenuator output is coupled, by means of cathode follower V317A, to vertical preamplifier V317B. This stage supplies a signal to vertical deflection amplifier V318, which drives the vertical deflection plates of the CRT, V511. The video information is now plotted against a linear time base, produced by the sweep phantastron circuit, consisting of V311 and V309A. V309A supplies the driving voltage for V319, the horizontal deflection amplifier, which drives the horizontal deflection plates of the CRT.

g. A portion of the signal from vertical deflection amplifier V318 is amplified by sync amplifier V309B, which supplies a signal to V311, for purposes of synchronization. A portion of the output of V311 is coupled to blanking amplifier V312, which serves to blank out the return trace of the linear time base.

2-3. SMALL ABSOLUTE JITTER MEASUREMENT, BLOCK DIAGRAM DESCRIPTION (See figures 2-3 and 2-8.)

a. Restatement of Definition. Absolute jitter is defined as the peak-to-peak time deviation of the period of a pulse train, with respect to the time representing the nominal period, as determined by the pulse repetition rate. In the measurement of absolute jitter, the reference channel is not used; only the signal channel and afc-controlled crystal oscillator circuits are employed.

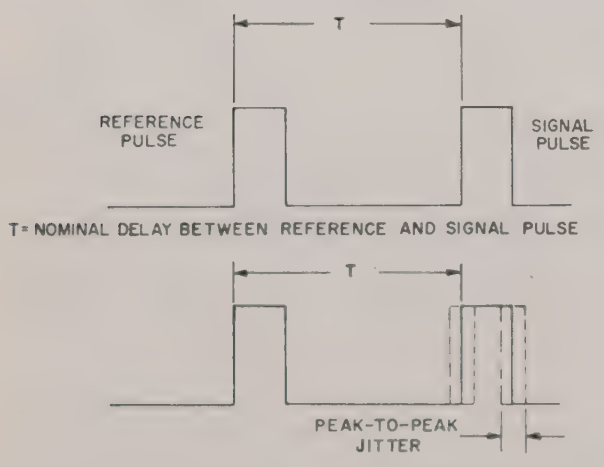

T
REFERENCE PULSE
SIGNAL PULSE
T= NOMINAL DELAY BETWEEN REFERENCE AND SIGNAL PULSE
T
PEAK-TO-PEAK JITTER
RELATIVE JITTER-DEFINED AS THE TIME DEVIATION OF ONE PULSE WITH RESPECT TO A REFERENCE PULSE

Figure 2-2. Relative Jitter, Waveform Time Chart

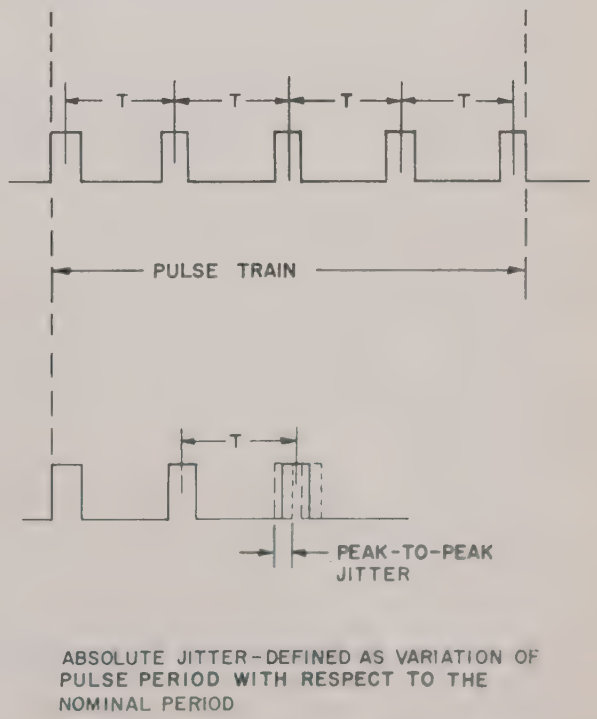


Figure 2-3. Absolute Jitter, Waveform Time Chart

b. The pulse signal under investigation is applied to cathode follower and signal phase inverter V401, which couples the signal to the slicer, cathode follower, peak detector, and feedback amplifier networks (CR401, CR402, V404, and V405). The output of this network is applied through trigger amplifier V402, to trigger signal cathode follower V403A. Trigger amplifier V101A amplifies the signal and enables gated multivibrator V102. When triggered, V102 generates a pulse of approximately 100 microseconds. This pulse is applied to gating cathode follower V103A, as well as to cathode follower sweep gate V101B. V101B serves to gate the horizontal sweep.

c. V103A is connected across the tuned circuit of gated 5 mc oscillator V103B. In the absence of the gating pulse, V103A conducts heavily, and constitutes a low-impedance shunt across the oscillator. The gate multivibrator pulse applied to V103A cuts it off. The shunt across V103B is thus removed, and V103B oscillates at 5 mc, for a period of time determined by the duration of the pulse generated by V102. V103B applies a signal through phase inverter V104, and the PHASE control, to signal oscillator amplifier V105. (The PHASE control has no effect on the signal in this measurement.) V105 amplifies the 5 mc signal and couples it to driver V106. The control grid of phase detector V107 is driven by this signal.

d. A reference signal is provided by 5 mc crystal reference oscillator, V206. This signal, applied to 5 mc crystal reference driver V205, drives the suppressor grid of phase detector V107. The output of the phase detector will be proportional to any phase difference between the signal and the reference pulses. This difference represents the phase angle between (1) the pulse jitter, and (2) the repetition rate of the train of pulses of which it is a part. Variations in phase difference will result in changes of the output of V107. Tube V108A applies a signal to both the calibrated attenuator and to cathode follower V108B, which includes a detector circuit. The function of V108B is to furnish an afc control voltage that is applied to the 5 mc crystal reference afc control stage, V207. This stage is connected to crystal reference oscillator V206, and serves to correct for short-term changes in oscillator frequency.

e. The attenuator is used to divide the phase detector output by known factors, providing progressive scale factors of 1, 0.1, and 0.05, corresponding to 100, 10, and 5 millimicroseconds. The output of the attenuator is applied to cathode follower V317A, and is amplified by V317B. This signal is applied to vertical deflection amplifier V318. The remainder of the circuit action is identical to that which occurs when making relative jitter measurements. (See paragraph 2-2.) For the balance of the sweep circuitry block diagram, refer to figure 2-7.

2-4. PULSE WIDTH JITTER MEASUREMENT, BLOCK DIAGRAM DESCRIPTION (See figures 2-4 and 2-9.)

a. Restatement of Definition. Pulse width jitter is defined as the peak-to-peak time deviation between the leading and trailing edges of a recurrent pulse. For the measurement of pulse width jitter, the signal channel circuits and part of the reference channel circuits are employed. The signal for the reference channel is derived from the internal circuitry, and requires no external signal source.

b. The pulse to be analyzed is applied to cathode follower and signal phase inverter V401 through the input jack. The output of V401 is applied to the slicer, cathode follower, peak detector, and feedback amplifier networks (CR401, CR402, V404, and V405). The signal from these networks is amplified by trigger amplifier V402, and is coupled to trigger signal cathode follower V403A, which couples the trigger signal to a clipping and differentiating circuit. This circuit supplies negative-going pulses to trigger amplifier V407. These negative-going pulses are coincident with the trailing edge of the positive input pulse, and represent the reference pulse. Trigger amplifier V101A triggers multivibrator V102, which generates a pulse of approximately 100 microseconds duration. The output of V102 is applied to gating cathode follower V103A, as well as to cathode follower sweep gate V101B. V101B is coupled to the horizontal phantastron oscillator circuit, to initiate horizontal sweep at the proper time, in relation to the input pulse.

c. V103A is connected across the resonant network of gated oscillator V103B, and normally constitutes a low-impedance shunt, which prevents V103B from oscillating. When the input signal is applied to V103A, this half of the tube is cut off. With the shunt removed, V103B will now oscillate at 5 mc for a period of time representing the time period of the pulse generated by V102. The signal developed by V103B is applied to phase inverter network V104. By means of the PHASE control, the phase difference between the incoming pulse and the reference oscillator, occurring over a long period of time, can be set to equal zero, as an average value. The signal transferred through V105 is amplified by signal driver V106 and is applied to the control grid of phase detector V107.

d. The negative-going pulses from the clipping and differentiating circuit are amplified by V407. Cathode follower V403B couples this signal to trigger amplifier V201A, which is connected across, and enables, gated multivibrator V202. The output of V202, a pulse of approximately 100 microseconds duration, is applied to gating

cathode follower V203A. Tube V203A represents a shunt across the tuned network of the 5 mc gated oscillator V203B. When the signal is applied to V203A, the tube is cut off, the shunt is removed, and V203B will oscillate for approximately 100 microseconds. V204 amplifies the signal from V203B and drives the suppressor grid of phase detector V107. As a result of the applied signals, V107 will deliver a train of pulses whose pulse width variations will be proportional to the phase difference between the two rf pulses. Cathode follower V108A transfers this video information to both a calibrated attenuator as well as to cathode follower V108B, which furnishes a signal to a ratio detector network, not used in this application.

e. Since the peak-to-peak output of phase detector V107 is equivalent to a maximum phase shift of 180 degrees (or 0.1 microsecond), the calibrated attenuator is used to divide the phase detector output by known factors providing progressive scale factors of 1, 0.1, and 0.05, corresponding to 100, 10, and 5 millimicroseconds. The attenuator output voltages drive cathode follower V317A. The balance of the circuitry for display of the pulse width jitter is now identical with that employed in displaying the other jitter information.

2-5. SMALL JITTER DISTURBANCE FREQUENCY MEASUREMENT, BLOCK DIAGRAM DESCRIPTION (See figure 2-5.)

a. Disturbance frequency is the frequency of the jitter being measured. In some cases, the frequency of the jitter is fixed; in others, it is of a random nature. For the measurement and display of small jitter disturbance frequency, the setting of the DISPLAY switch, in USE position, selects the additional circuits indicated in the block diagram. The function of these stages is described in this paragraph. The video signal from cathode follower V108B is applied, through switch section S301D, to cathode follower V314A. The output of V314A is coupled to triode hold circuit V316 (a boxcar circuit), which is normally cut off. The video signal, therefore, cannot pass through V316, unless this tube is triggered by a signal from blocking oscillator V308A.

b. Reference to the lower portion of figure 2-5 shows that the signal from cathode follower V403A is applied to signal trigger amplifier V301. The amplified signal from V301 triggers phantastron delay generator V302, V303 into action. The phantastron delay generator triggers blocking oscillator V308A. The sampling trigger obtained from this oscillator is coupled to, and actuates, triode hold circuit V316. This circuit samples the voltage from cathode follower V314A, when actuated by the sampling trigger, and holds this level until the next sampling trigger occurs. The output of the hold circuit is the disturbance frequency component of the pulse jitter. The disturbance frequency waveform information from V316 is coupled to the video preamplifier through cathode follower V314B.

c. The output of the hold circuit represents the frequency of the pulse jitter disturbance, or noise present with the pulse. This information appears on the CRT display as a stepped waveform with each step representing the instantaneous pulse or noise displacement (so-called "jitter") of the pulse, and with the overall waveform representing the total jitter waveshape.

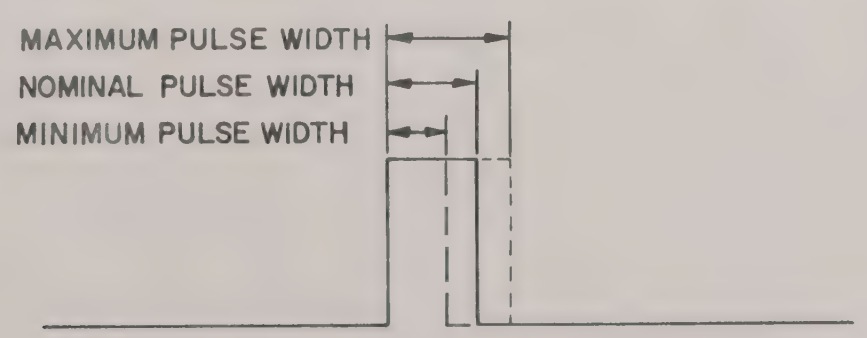

MAXIMUM PULSE WIDTH
NOMINAL PULSE WIDTH
MINIMUM PULSE WIDTH
PULSE WIDTH JITTER-DEFINED AS VARIATION OF PULSE WIDTH WITH RESPECT TO THE NOMINAL PULSE WIDTH, IN A RECURRENT PULSE TRAIN

Figure 2-4. Width Jitter, Waveform Time Chart

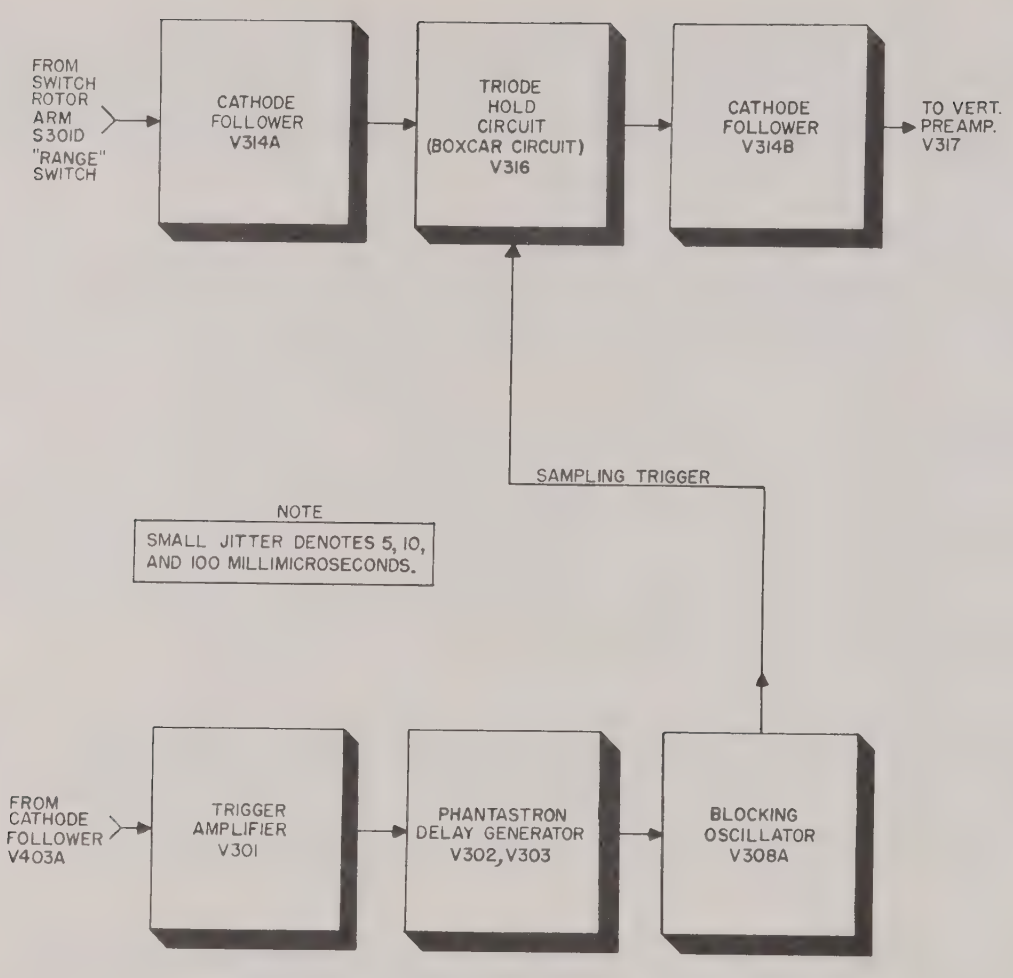

FROM SWITCH ROTOR ARM S301D "RANGE" SWITCH
CATHODE FOLLOWER V314A
TRIODE HOLD CIRCUIT (BOXCAR CIRCUIT) V316
CATHODE FOLLOWER V314B
TO VERT. PREAMP. V317
SAMPLING TRIGGER
NOTE
SMALL JITTER DENOTES 5, 10, AND 100 MILLIMICROSECONDS.
FROM CATHODE FOLLOWER V403A
TRIGGER AMPLIFIER V301
PHANTASTRON DELAY GENERATOR V302, V303
BLOCKING OSCILLATOR V308A

Figure 2-5. Small Jitter Disturbance Frequency Measurement, Block Diagram

2-6. LARGE ABSOLUTE JITTER AND DISTURBANCE FREQUENCY MEASUREMENT, BLOCK DIAGRAM DESCRIPTION (See figure 2-6.)

a. Disturbance frequency is the frequency of the jitter being measured. In some cases, the frequency of the jitter is fixed; in others, it is of a random nature. For the measurement of large jitter and disturbance frequency, the setting of the DISPLAY switch selects the additional circuits indicated on the block diagram. The signal trigger from cathode follower V403A is amplified by V301A, and applied, through cathode follower V301B, to delay phantastron generator V302, V303. This output signal is coupled, by cathode follower V304A, to phantastron delay generator V306, V304B. The delay signal generated by this phantastron is amplified by V307, and actuates phantastron ramp generator V313. Ramp generator V313 applies a signal to hold circuit V316, through cathode follower V314A. V316 is normally cut off until it is triggered by a signal from blocking oscillator V308, which is enabled by a signal trigger derived from the input signal. The output from V316 is coupled to the video preamplifier by cathode follower V314B.

b. For this particular measurement, the direct pulse jitter is not used for video information. Instead, the pulse jitter is used to control the generation of the sampling trigger signal. This sampling trigger then actuates the hold circuit, which passes a portion of the sawtooth waveform, developed by ramp generator V313. The portion of the output of V313 that is passed by V316 has an amplitude which represents the level of pulse jitter at that particular instant in time.

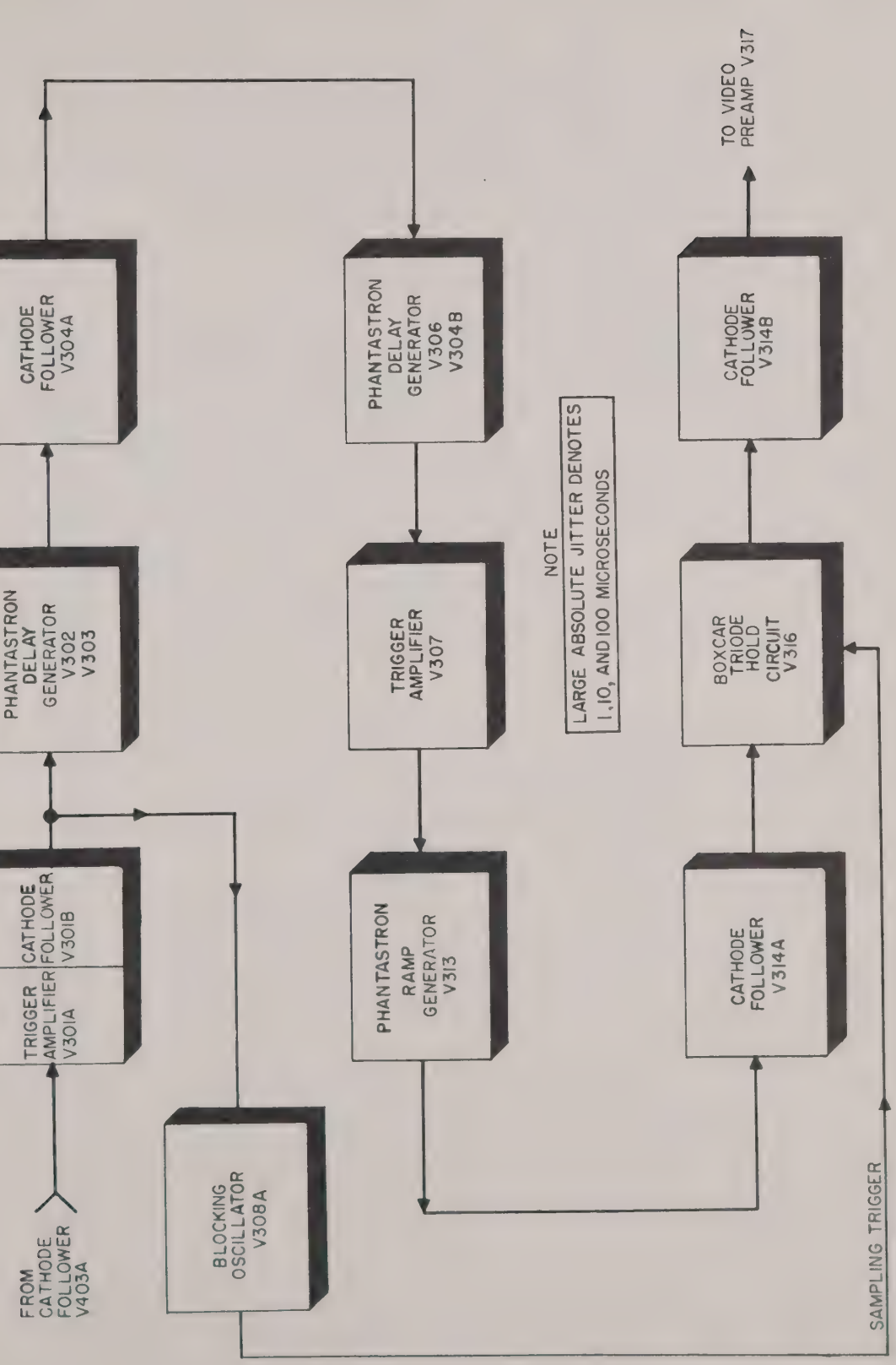


Figure 2-6. Large Absolute Jitter and Disturbance Frequency Measurement, Block Diagram

NOTE

The following paragraphs (2-7 through 2-20) present a more detailed analysis than that given in the preceding block diagram descriptions. In paragraphs 2-7 through 2-13, the discussion consists of signal tracing through each of the block diagrams, for the purpose of assisting in the maintenance of the instrument. In paragraphs 2-14 through 2-20, an analysis is presented of the unconventional circuits utilized in the instrument.

2-7. DETAILED SIGNAL TRACING, RELATIVE JITTER MEASUREMENT (See figures 2-1, 2-2, and 2-7.)

a. General. Relative jitter is the peak-to-peak time deviation of the leading edge of one pulse, with respect to the leading edge of a reference pulse. This type of measurement might be made, for example, to determine the jitter introduced between the input and output pulses of triggered circuits (in order to determine the figure of merit of that particular circuit). For this purpose, the time position of the output pulse is measured with respect to the time position of the input pulse. The input pulse is used as the reference pulse and, after amplification and shaping, initiates the 5 mc reference oscillator, whose phase is then used for comparison with the phase of a 5 mc oscillator which has been initiated by the output pulse. The comparison of phases occurs in a gated beam phase detector, which converts the relative phase variations of the two gated signals into pulses of plate current, of varying pulse width. These variations are displayed on the internal oscilloscope. Their magnitude is measured to determine the relative jitter. This video information is also available for presentation on an external oscilloscope.

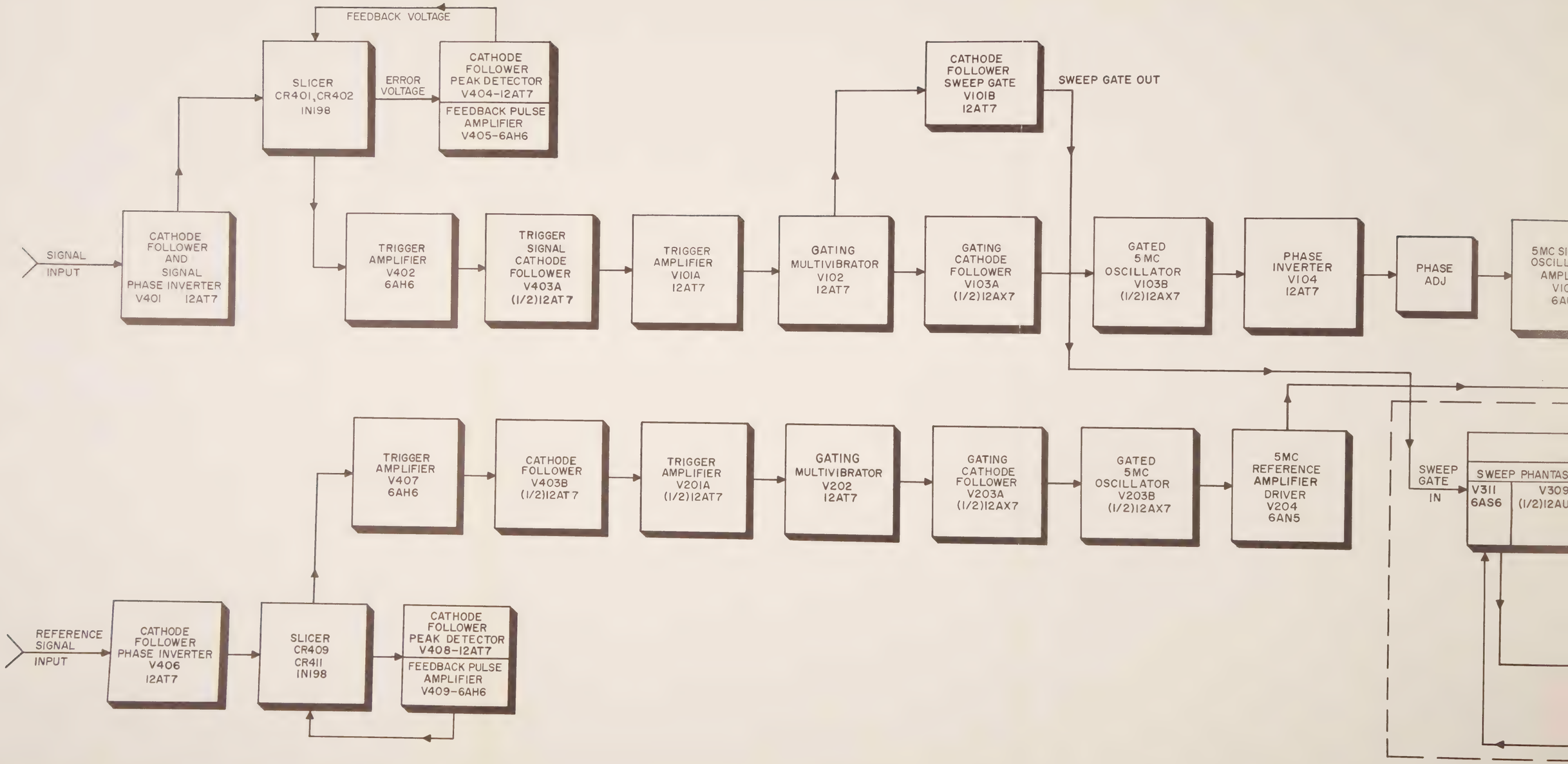
b. Analysis. (See figure 2-7.) The reference pulse is applied to the input of the reference channel. The signal pulse, whose jitter is to be measured, is applied to the signal channel input. The signal pulse is applied to inverter amplifier V401. (For detailed analysis of this circuit, see paragraph 2-15.) The output of this stage, which is always negative, is applied to a slicer network. (For a detailed analysis of this circuit, see paragraph 2-16.)

(1) A positive d-c voltage of the same amplitude as the signal peak is applied to the slicer network from a bias generator, composed of amplifier V405 and peak detector cathode follower V404. The bias generator operates with the slicer network as an electronic error-feedback servomechanism to maintain the slicer bias equal to the input signal peak, thus compensating for any increase or decrease in the signal pulse applied to the slicer network. The output signal from the slicer network is sliced at the 50% point of the amplitude of the input signal. This signal is amplified by V402 and is coupled, by cathode follower V403A, to trigger amplifier V101A.

(2) The signal from V101A triggers V102, which is a cathode-coupled monostable multivibrator. The multivibrator provides a pulse of approximately 100 microseconds in width. The output pulse from gate multivibrator V102 is coupled to gating cathode follower V103A, which is connected across a gated 5 mc oscillator, V103B. The pulse gate enables the 5 mc oscillator, during its 100-microsecond width. The pulse gate is also applied to the grid of sweep gate cathode follower V101B. The pulse from V101B is applied to sweep phantastron tube V311, along with the sync signal from sync amplifier V309B. The sweep gate pulse serves to ensure that the horizontal sweep starts at the same time as the leading edge of the input pulse applied to the vertical deflection amplifier.

(3) The output from 5 mc oscillator V103B is simultaneously applied to the grids of V104A and V104B, the phase inverter. The 5 mc output, which appears across the variable PHASE control, is coupled to the grid of 5 mc oscillator amplifier V105. The rf signal from V105 is amplified by 5 mc signal driver V106. The high level output of V106 is applied to the control grid of gated beam phase detector V107. A similar action has occurred in the reference channel which, from V201 through V203, is identical to the signal channel stages V101 through V103. The rf pulse from gated 5 mc oscillator V203B is amplified by 5 mc reference driver V204. Tube V204 drives the suppressor grid (functioning as a control grid) of gated beam phase detector V107. The detector then compares the phase of the two 5 mc signals.

(4) If jitter is present, there is a variable phase difference which V107 converts into plate current pulses of varying pulse widths. These variations are directly proportional to the amount of jitter. (Refer to paragraph 2-18 for a detailed analysis of phase detector V107.) The output of the phase detector is a train of pulses, whose maximum peak-to-peak pulse width amplitude (corresponding to a phase difference of 180 degrees) is equivalent to


FEEDBACK VOLTAGE
SLICER CR401, CR402 IN198
ERROR VOLTAGE
CATHODE FOLLOWER PEAK DETECTOR V404-12AT7
FEEDBACK PULSE AMPLIFIER V405-6AH6
CATHODE FOLLOWER SWEEP GATE V101B 12AT7
SWEEP GATE OUT
SIGNAL INPUT
CATHODE FOLLOWER AND SIGNAL PHASE INVERTER V401 12AT7
TRIGGER AMPLIFIER V402 6AH6
TRIGGER SIGNAL CATHODE FOLLOWER V403A (1/2)12AT7
TRIGGER AMPLIFIER V101A 12AT7
GATING MULTIVIBRATOR V102 12AT7
GATING CATHODE FOLLOWER V103A (1/2)12AX7
GATED 5MC OSCILLATOR V103B (1/2)12AX7
PHASE INVERTER V104 12AT7
PHASE ADJ
TRIGGER AMPLIFIER V407 6AH6
CATHODE FOLLOWER V403B (1/2)12AT7
TRIGGER AMPLIFIER V201A (1/2)12AT7
GATING MULTIVIBRATOR V202 12AT7
GATING CATHODE FOLLOWER V203A (1/2)12AX7
GATED 5MC OSCILLATOR V203B (1/2)12AX7
5MC REFERENCE AMPLIFIER DRIVER V204 6AN5
SWEEP GATE IN
SWEEP PHANTAS
V311 6AS6
REFERENCE SIGNAL INPUT
CATHODE FOLLOWER PHASE INVERTER V406 12AT7
SLICER CR409 CR411 IN198
CATHODE FOLLOWER PEAK DETECTOR V408-12AT7
FEEDBACK PULSE AMPLIFIER V409-6AH6

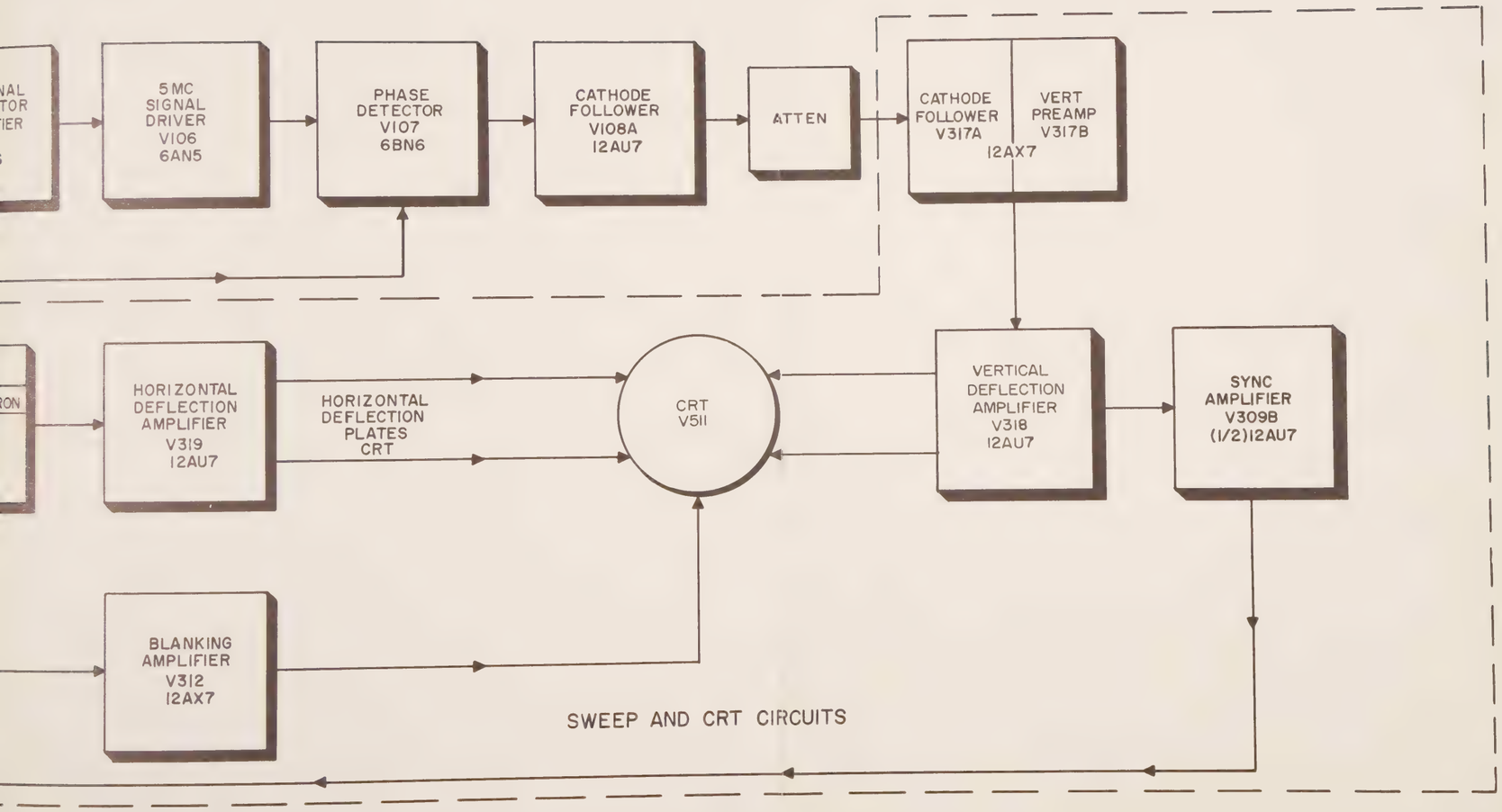


Figure 2-7. Relative Jitter Measurement, Block Diagram

100 millimicroseconds*. A calibrated attenuator is used to divide the phase detector output by successive scale factors of 1.0, 0.1, and 0.05, corresponding to 100 millimicroseconds, 10 millimicroseconds, and 5 millimicroseconds. The phase detector output signal is applied through cathode follower V108A to the grid of cathode follower V317A, which drives vertical preamplifier V317B. The amplified video signal is coupled to vertical deflection amplifier V318. The signal from V318 appears across the vertical deflection plates of the CRT, and is plotted against an internally-generated linear time base which is applied to the horizontal deflection plates.

2-8. DETAILED SIGNAL TRACING, SMALL ABSOLUTE JITTER MEASUREMENT (See figures 2-3 and 2-8.)

a. General. Absolute jitter is defined as the peak-to-peak time deviation of the period of a pulse train, with respect to the time representing the nominal period, as determined by the pulse repetition rate. The signal channel stages which are used to provide a 5 mc gated pulse to phase detector V107 for relative jitter measurements, are also employed for absolute jitter measurement. The reference channel is not used for this type of measurement, as no reference pulse is available. The jitter, in this case, is measured with respect to the pulse repetition rate. The constant pulse repetition rate acceptance range of this equipment is 50 to 6,000 pps.

b. Analysis. (See figure 2-8.) The nominal pulse repetition rate of the input pulses is used as a reference for the determination of absolute pulse jitter. Because a frequency of 5 mc is used for the gated 5 mc signal oscillator, a 5 mc signal must be employed in order to compare the reference with the gated 5 mc signal in the signal channel. This is accomplished by tuning an extremely stable 5 mc oscillator to a frequency which represents a harmonic of the average pulse repetition rate.

(1) Since the average prf is in the range of 50-6,000 cps, this means that the 5 mc oscillator is tunable 6,000 cps around the nominal 5 mc center frequency. The output of this 5 mc oscillator is continuous. This cw 5 mc signal is obtained from crystal oscillator V206, which is controlled by the afc reactance tube circuit, V108B, V207. The afc controlled crystal oscillator, V206, is used only when making absolute jitter measurements. The pulse output of cathode follower V108B, at the repetition rate of the input signal, is applied to the detector network, which includes crystal diodes CR102 and CR103 (see figure 6-2).

(2) The output of the detector is applied to the control grid of reactance tube V207 (the 5 mc crystal reference oscillator afc control). The crystal oscillator tuning range capacitor, C232, can be adjusted to permit oscillator V206 to operate at a frequency of 5 mc plus or minus 3 kc. This provision permits the oscillator to be tuned to some harmonic of the average repetition rate of the signal input. The afc control circuit locks V206 to this average repetition rate and thus serves to compensate for long-term drift, maintaining the average phase at zero.

(3) The cw 5 mc signal generated by V206 is amplified by V205 and applied to the suppressor grid of phase detector V107. Any variation in the phase difference between the 5 mc gated signal and the 5 mc reference signal appears as a variation of the jitter on the video presentation.

2-9. DETAILED SIGNAL TRACING, LARGE ABSOLUTE JITTER MEASUREMENT (See figures 2-3 and 2-6.)

a. General. Absolute jitter is defined as the peak-to-peak time deviation of the period of a pulse train, with respect to the time representing the nominal period, as determined by the pulse repetition rate. In the measurement of large absolute jitter, the same circuitry is used as in the measurement of large disturbance frequency. The only difference is in the sweep rate used for visual display on the self-contained CRT. For the large jitter measurement, a fast sweep speed is employed. When making the above measurements, only the signal input, phantastron, hold, and display circuits are used. The signal tracing of small absolute jitter has been given in paragraph 2-8; only those circuits employed for large absolute jitter and large disturbance frequency measurements will be described in this paragraph.

b. Analysis. (See figure 2-6.) The pulse train under investigation for large absolute jitter or disturbance frequency is applied to the input of the signal channel only. This pulse train is inverted, sliced, and amplified. (For detailed analysis of the signal channel circuits, refer to paragraphs 2-15 and 2-16.) This amplified output signal is coupled to cathode follower V403A. The output is applied to the grid of trigger amplifier V301A, and is transferred by cathode follower V301B to the grid of blocking oscillator V308, the suppressor grid of V302 and the control grid of V303B. V302 and V303 form a delay phantastron generator.

* 180 degrees is one-half period of the 5 mc signals. Since the period corresponding to 5 mc is 0.2 microsecond, one-half period is 0.1 microsecond or 100 millimicroseconds. This period is as accurate as the 5 mc frequency.

(1) The output of V303 is coupled by cathode follower V304A to delay phantastron generator V304B, V306. The series added delays of V302, V303 and V304, V306 are applied to and amplified by trigger amplifier V307. The output of V307 triggers phantastron ramp generator V313.

(2) The signal generated by V313 is coupled by cathode follower V314A to the boxcar triode hold circuit V316. (For a detailed description of this circuit, refer to paragraph 2-20.) The signal generated by V308 (triggered by the output from V301B) is also applied to boxcar hold circuit V316.

(3) The output of V316 is controlled not only by the signal applied from V314A, but also by the signal coupled from V308. When the sampling trigger signal from V308 enables V316, a sawtooth from the series phantastrons (delayed with respect to the sampling trigger signal) is also applied to V316. Both the phantastron and sampling trigger signals are initiated by the same trigger signal from V301B. When the second pulse (or trigger) signal from the pulse train triggers V308, the output of V308 will sample a portion of the slope of the sawtooth output from V313. The pulse signal and the ramp generator signal are separated by a given time interval (nominally set so that the pulse samples the center of the slope). Therefore, any time deviation of the following pulse (or pulses) will cause the trigger to sample the output of V313 at a time before or after the sample time of the preceding pulse. This time variation is determined by the amplitude of the pulse jitter, and occurs at the same rate as the frequency of the pulse jitter.

2-10. DETAILED SIGNAL TRACING, WIDTH JITTER MEASUREMENT (See figure 2-9.)

a. General. Width jitter is defined as the peak-to-peak time deviation between the leading and trailing edges of a recurrent pulse. The signal channel stages are identical to those used for relative jitter measurement. In addition, a clipping and differentiating circuit has been included in the signal channel (which is used only for pulse width jitter measurements). Only a portion of the reference channel is used, since no external reference signal is required.

b. Analysis. The positive pulse from amplifier V402, in the signal channel, is applied to cathode follower V403A. The output of V403A is applied to the clipper-differentiator circuits, as well as to amplifier V101A. The positive pulse is coupled to the clipper circuit. After being clipped to remove unwanted spikes, the signal is aplied to a differentiating network. A negative pulse, coincident with the trailing edge of the positive input pulse, is thus obtained, and is amplified by V407 in the reference channel. The operation of both the signal and reference channels, as well as the output circuitry, is now identical to that when measuring relative jitter. (See paragraph 2-7.)

2-11. DETAILED SIGNAL TRACING, SMALL JITTER DISTURBANCE FREQUENCY MEASUREMENT (See figure 2-5.)

a. General. Pulse jitter disturbance frequency measurement is the measurement of the pulse jitter frequency present, or the rate at which the pulse time variations take place. There are two types of disturbance measurements. These are: (1) frequency, and (2) waveform of the disturbance frequency.

b. Analysis. When making this measurement, all circuits used for a jitter measurement are employed in their usual manner. Only those additional circuits employed for this measurement are discussed. These additional circuits consist of portions of the circuitry used for the large disturbance frequency measurement.

(1) When in the millimicrosecond ranges, the switch rotor arm (S301D) selects and applies to cathode follower V314A the output of cathode follower V108A. This signal contains the video information representing the pulse jitter present in the pulse train. The output of V314A is applied to triode hold circuit V316, which is held at cutoff until a sampling trigger from blocking oscillator V308A arrives to enable the circuit.

(2) A trigger signal from cathode follower V403A is applied to trigger amplifier V301. The output from V301 triggers phantastron delay generator V302, V303. At the end of the phantastron sawtooth period, blocking oscillator V308A is triggered. The sampling trigger from V308A is applied to and enables V316 (boxcar circuit).

(3) The triggering of V308A occurs at an interval of time which corresponds to maximum jitter amplitude of the pulse being sampled. The waveform then appears on the CRT display. For frequency measurement, refer to the method outlined in paragraph 3-5b.

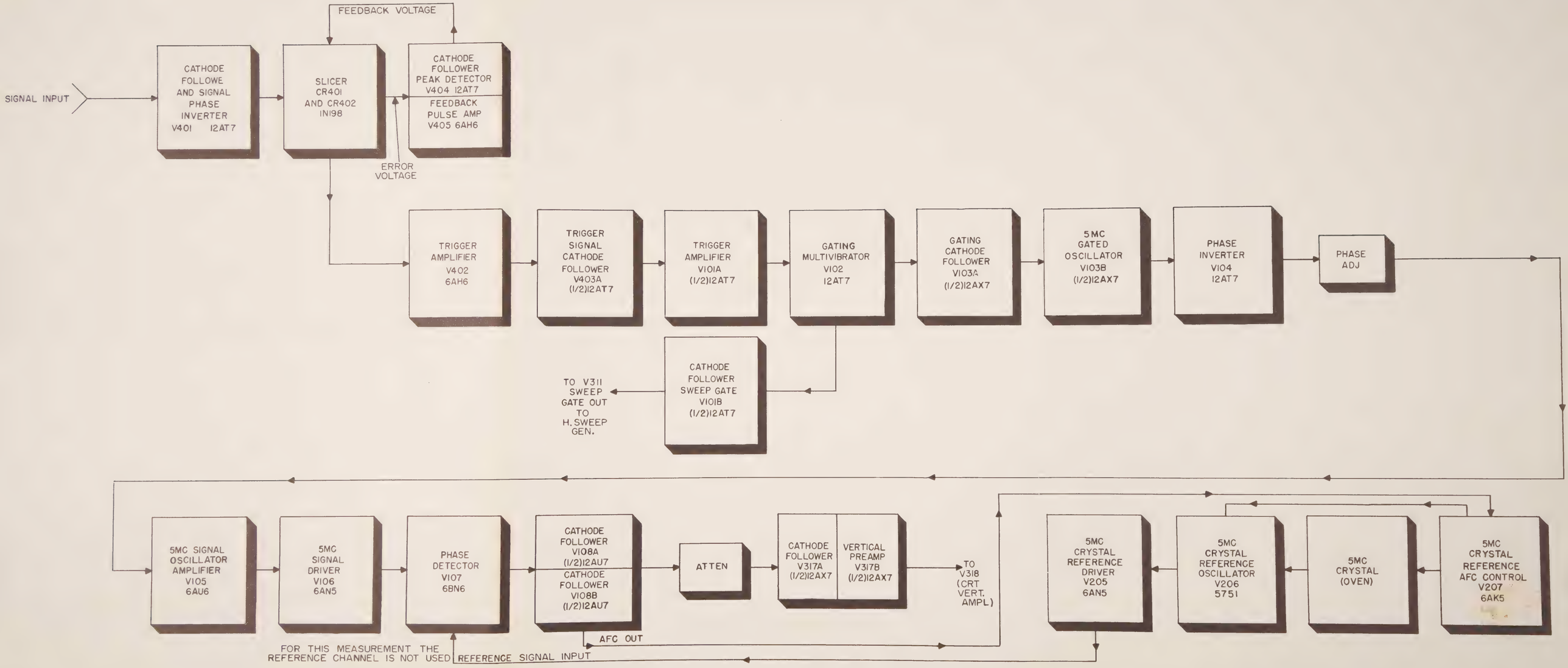

FEEDBACK VOLTAGE
SIGNAL INPUT
CATHODE FOLLOWE AND SIGNAL PHASE INVERTER V401 12AT7
SLICER CR401 AND CR402 IN198
CATHODE FOLLOWER PEAK DETECTOR V404 12AT7
FEEDBACK PULSE AMP V405 6AH6
ERROR VOLTAGE
TRIGGER AMPLIFIER V402 6AH6
TRIGGER SIGNAL CATHODE FOLLOWER V403A (1/2)12AT7
TRIGGER AMPLIFIER V101A (1/2)12AT7
GATING MULTIVIBRATOR V102 12AT7
GATING CATHODE FOLLOWER V103A (1/2)12AX7
5MC GATED OSCILLATOR V103B (1/2)12AX7
PHASE INVERTER V104 12AT7
PHASE ADJ
TO V311 SWEEP GATE OUT TO H. SWEEP GEN.
CATHODE FOLLOWER SWEEP GATE V101B (1/2)12AT7
5MC SIGNAL OSCILLATOR AMPLIFIER V105 6AU6
5MC SIGNAL DRIVER V106 6AN5
PHASE DETECTOR V107 6BN6
CATHODE FOLLOWER V108A (1/2)12AU7
CATHODE FOLLOWER V108B (1/2)12AU7
ATTEN
CATHODE FOLLOWER V317A (1/2)12AX7
VERTICAL PREAMP V317B (1/2)12AX7
TO V318 (CRT VERT. AMPL)
AFC OUT
FOR THIS MEASUREMENT THE REFERENCE CHANNEL IS NOT USED
REFERENCE SIGNAL INPUT
5MC CRYSTAL REFERENCE DRIVER V205 6AN5
5MC CRYSTAL REFERENCE OSCILLATOR V206 5751
5MC CRYSTAL (OVEN)
5MC CRYSTAL REFERENCE AFC CONTROL V207 6AK5

Figure 2-8. Small Absolute Jitter Measurement, Block Diagram

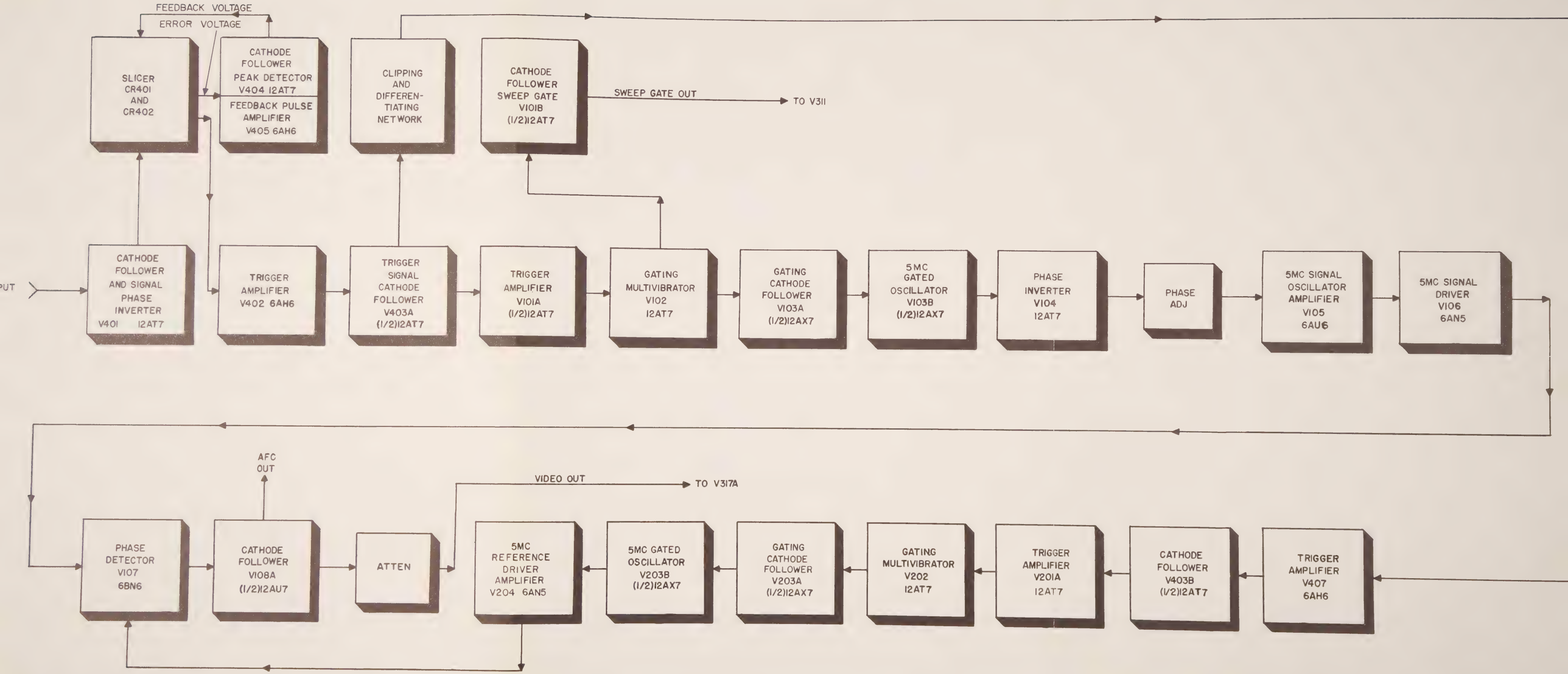

FEEDBACK VOLTAGE
ERROR VOLTAGE
SLICER CR401 AND CR402
CATHODE FOLLOWER PEAK DETECTOR V404 12AT7
FEEDBACK PULSE AMPLIFIER V405 6AH6
CLIPPING AND DIFFEREN-TIATING NETWORK
CATHODE FOLLOWER SWEEP GATE V101B (1/2)12AT7
SWEEP GATE OUT
TO V311
PUT
CATHODE FOLLOWER AND SIGNAL PHASE INVERTER V401 12AT7
TRIGGER AMPLIFIER V402 6AH6
TRIGGER SIGNAL CATHODE FOLLOWER V403A (1/2)12AT7
TRIGGER AMPLIFIER V101A (1/2)12AT7
GATING MULTIVIBRATOR V102 12AT7
GATING CATHODE FOLLOWER V103A (1/2)12AX7
5MC GATED OSCILLATOR V103B (1/2)12AX7
PHASE INVERTER V104 12AT7
PHASE ADJ
5MC SIGNAL OSCILLATOR AMPLIFIER V105 6AU6
5MC SIGNAL DRIVER V106 6AN5
AFC OUT
VIDEO OUT
TO V317A
PHASE DETECTOR V107 6BN6
CATHODE FOLLOWER V108A (1/2)12AU7
ATTEN
5MC REFERENCE DRIVER AMPLIFIER V204 6AN5
5MC GATED OSCILLATOR V203B (1/2)12AX7
GATING CATHODE FOLLOWER V203A (1/2)12AX7
GATING MULTIVIBRATOR V202 12AT7
TRIGGER AMPLIFIER V201A 12AT7
CATHODE FOLLOWER V403B (1/2)12AT7
TRIGGER AMPLIFIER V407 6AH6

Figure 2-9. Width Jitter Measurement, Block Diagram

2-12. DETAILED SIGNAL TRACING, LARGE DISTURBANCE FREQUENCY MEASUREMENT

The circuitry used for this measurement is the same as is used for the measurement of large absolute jitter. For the signal tracing analysis of this measurement, refer to paragraph 2-9 and figure 2-6.

2-13. POWER SUPPLY CIRCUITS

a. The power supplies used in this equipment are of conventional design, and are of the regulated type. Except for the series string regulated filaments, these circuits may be analyzed by reference to the schematic circuit diagram, figure 6-4.

b. For a detailed analysis of the series string regulated filament circuit, refer to paragraph 2-19.

2-14. ANALYSIS OF SPECIAL CIRCUITS

a. General. The basic circuits of the Polarad Model PJ-1 Pulse Jitter Tester are of a conventional nature, and do not require detailed analysis. There are, however, a few circuits which are somewhat unique in their application to the pulse jitter tester. In the following discussion, refer to the simplified schematic diagrams, figures 2-10 through 2-15, which cover the special circuits analyzed in the following paragraphs:

(1) Inverter-amplifier V401, CR401, and CR402 (figure 2-10);
(2) Slicer and feedback circuit CR403, CR404, V404, and V405 (figure 2-11);
(3) 5 mc gated oscillator V103 (figure 2-12);
(4) Phase detector V107 (figure 2-13);
(5) The series string regulated filament circuit (figure 2-14);
(6) Hold (boxcar) circuit V314, V316 (figure 2-15).

2-15. INVERTER-AMPLIFIER STAGE (See figure 2-10.)

The pulse jitter tester accepts and analyzes the jitter of positive or negative pulses having a peak amplitude of from 5 to 50 volts. If an external reference signal is used, it is applied to REFERENCE INPUT jack J501. The signal whose jitter is to be measured is applied to SIGNAL INPUT jack J502. The input signal applied to J502 is coupled by capacitors C401 and C403 to the grids, pins 2 and 7 respectively, of inverter-amplifier V401. This stage, together with its associated circuit components, is essentially a unipolar converter. Tube V401 delivers only a negative polarity output, regardless of the polarity of the input signal. This result is achieved by the following circuit action:

a. Inverter-amplifier V401 is a twin triode. The "A" section functions as a cathode follower, and the "B" section serves as a phase inverter. The cathode follower section has its grid returned, through grid resistor R401, to the junction of cathode resistors R402 and R403. The cathode of V401A is approximately 50 volts positive with respect to ground. The grid return resistor, R401, places the grid at a voltage of approximately 1.5 volts negative with respect to the cathode, thus operating the tube at normal class A characteristics. However, the grid is approximately 48 volts positive above ground. Thus, in order for any signal to drive V401A beyond normal operating conditions, the input signal must exceed 50 volts in amplitude. Consider the case of a negative input signal applied to the grids of V401. When a large negative signal is applied, the phase inverter, Section B, is cut off. With a small negative signal applied to V401, the phase inverter, section B, conducts slightly. Should conduction occur, a positive signal will be present at the plate, pin 6. This signal is coupled by capacitor C406 to crystal diode CR401. However, because of its polarity, CR401 does not conduct, and the signal from V401B is not applied to the slicer network. A negative signal appears at the cathode of V401A, pin 3; this signal is applied to crystal diode CR402, which conducts and passes the signal on to the slicer circuit.

b. If a positive signal is applied to the grids, cathode follower V401A conducts; a positive signal appears at the cathode and is coupled by capacitor C407 to crystal diode CR402. CR402 will not conduct when the signal is positive; thus no signal is applied to the slicer network. The positive signal applied to the grid of V401B, pin 7, appears as a negative output, at the plate, pin 6. This output is coupled by C406 to crystal diode CR401, which conducts and passes the signal on to the slicer network.

c. It can be seen that the amplifier-inverter stage provides a negative signal, of somewhat smaller amplitude than the input signal, regardless of the polarity of the input. Capacitor C402, in the cathode circuit of V401B, serves to equalize the response of the amplifier-inverter. Resistor R404 and capacitor C404 serve as a decoupling filter in the B+ supply to V401B.

2-16. SLICER AND FEEDBACK CIRCUIT (See figure 2-11.)

This circuit consists of a slicer network and a d-c bias feedback loop, composed of peak detector-cathode follower V404 networks and feedback pulse amplifier V405.

a. In analyzing the slicer network and accompanying feedback loop, that portion of the circuit containing R416, CR404, R418, amplifier V405, and detector cathode follower V404 will be analyzed first.

(1) The negative signal pulse from inverter-amplifier V401 is applied through resistor R416 to the junction of crystal diode CR404 and resistor and resistor R418. The polarity of crystal diode CR404 is such that it is an open circuit to the negative pulse. Resistors R416 and R418 are of equal value and, therefore, form a voltage divider so that approximately one-half of the input signal appears between the junction of R416, R418 and ground.

(2) The resultant signal is applied through coupling capacitor C424 and through crystal diode CR406 to the grid, pin 1, of the feedback pulse amplifier V405. This signal is amplified and inverted. The positive signal output is coupled by capacitor C421 from the plate, pin 5, to the grid, pin 7, of the peak detector section V404B. Resistor R429 and capacitor C419, in the cathode circuit of V404B, provide a long time-constant network, which is directly connected to the grid of the A section of V404.

(3) The cathode circuit of V404A also consists of a long time-constant network. The long time-constant circuits cause the networks to charge to a value very nearly representing the average d-c level of the signal pulse. The filtering effects of both circuits add in series, and furnish an almost pure d-c voltage. The positive signal is applied to the junction of resistors R417 and R418, Test Point 1. This voltage is nearly equal to the peak negative value of the signal input.

(4) When a second negative pulse appears at the input to the slicer, and it is less than the positive d-c bias at Test Point 2, the resultant voltage, at the junction of resistors R416, R418 and crystal diode CR404, will initially be positive. This positive voltage is effectively shorted to ground through crystal diode CR404; thus, the voltage at that point is zero. If the second negative pulse, however, is greater in amplitude than the developed d-c bias voltage, a negative pulse equal to one-half the difference between the input and bias voltages appears at the junction of resistors R416, R418, and crystal diode CR404, and at the input to the grid of amplifier V405.

b. It can be seen, therefore, that a negative output signal will be applied to the feedback loop only when the negative input to the slicer is greater in amplitude than the developed d-c bias. A larger negative input results in a larger positive d-c bias. The bias produced is approximately equal to the peak value of the input signal.

c. A similar circuit arrangement, consisting of resistors R413, R414, and R417, and crystal diode CR403, comprises the top portion of the slicer. Resistors R413 and R414 in parallel, form a voltage divider with, and provide one-half the value of, resistor R417. By an analysis similar to that used for the bottom portion of the slicer network, it can be shown that the output to coupling capacitor C413 appears when the magnitude of the input signal equals, or is larger than one-half of, its peak value. When the output is less than one-half its peak value, then the voltage at capacitor C413 is zero. By the action of the slicer, the negative input signal is sliced at its half-way point, and is slightly attenuated. The output to C413 and to the following amplifier stage V402 is, therefore, a negative signal of approximately one-third the input amplitude and approximately similar to the top half of the input waveshape. The bottom half of the input wave has been sliced away to permit the measurement of jitter at the 50% point of the input wave.

2-17. 5 MC GATED OSCILLATOR STAGE (See figure 2-12.)

a. This circuit provides a 5 mc signal, which is generated only during the period of the negative gate input. The phase of this signal, relative to the input trigger pulse, is always at a fixed relationship. Cathode follower V103A is normally conducting and its cathode current flows through L103, which is part of the 5 mc oscillator circuit. V103A acts as a low-impedance shunt across the resonant network of oscillator V103B. This low-impedance shunt prevents V103B from oscillating. A signal trigger pulse from trigger amplifier V101A, applied through capacitor C107, cuts V103A off. The cathode current through coil L103 ceases abruptly, causing ringing in L103, and the resonant circuit of L103 and C110, C113 starts to oscillate. V103B and its associated components, together with L103 and C110, C113, form a Colpitts oscillator. The output pulse from V101A is also used to trigger multivibrator V102, which generates a gate approximately 100 microseconds wide. (See figure 6-2.) This gate keeps V103A cut off for the duration of its period, and V103B continues to oscillate for approximately 100 microseconds.

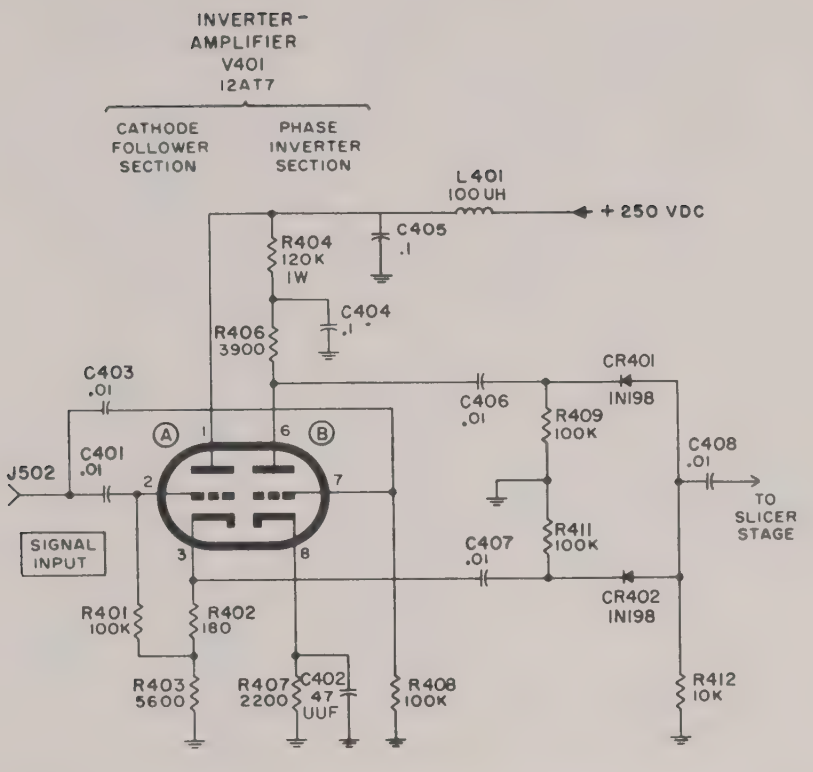


Figure 2-10. Inverter Amplifier Stage, Simplified Schematic Diagram

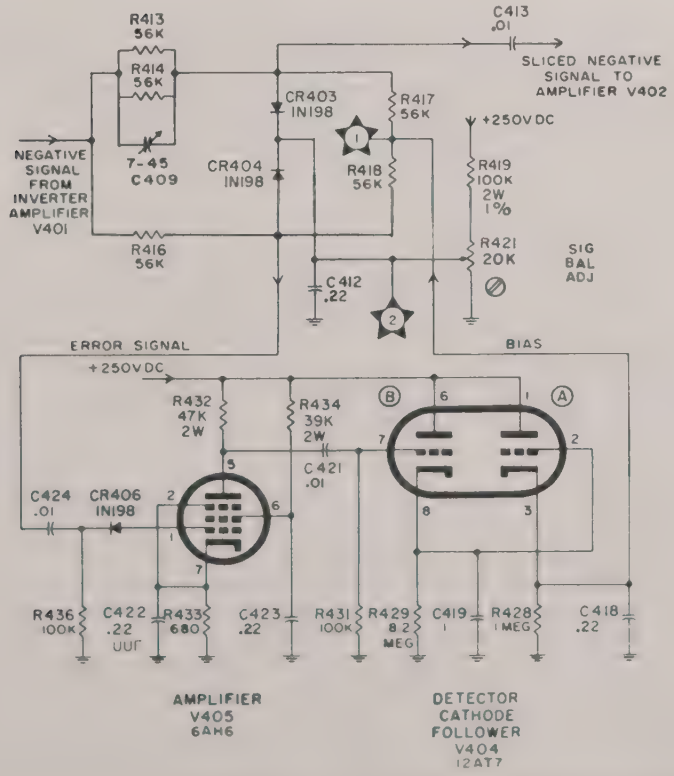


Figure 2-11. Slicer and Feedback Circuit, Simplified Schematic Diagram

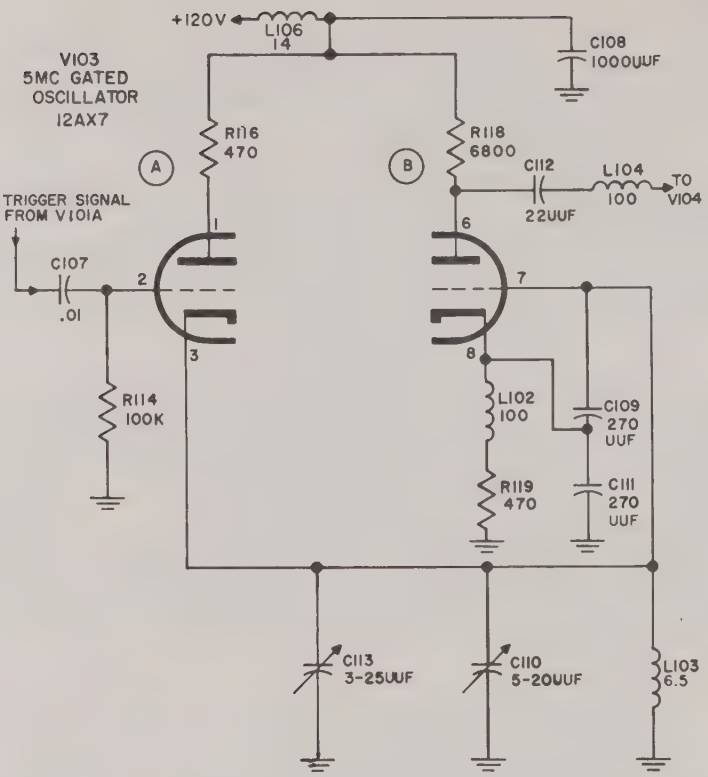


Figure 2-12. 5 Mc Gated Oscillator, Simplified Schematic Diagram

b. A portion of the output of gate multivibrator V102 is coupled through C103 to the grid of cathode follower V101B, and is used to provide a gating pulse for the CRT horizontal sweep circuit. This pulse serves to ensure that the horizontal sweep start-time coincides with the start of the oscillator gating pulse. The output of V103B is coupled to phase inverter V104; a variable capacitor (of special four quadrant design) in the output circuit of V104 permits adjustment of the phase of the gated 5 mc signal oscillator pulse signal, with respect to the reference signal.

2-18. PHASE DETECTOR (See figure 2-13.)

a. This stage uses a special tube, type 6BN6, specifically designed for "quadrature" detection of fm signals. The 6BN6 stage compares the phase of the signal-gated 5 mc oscillations (from V106) with the phase of the reference-gated 5 mc oscillations (from V204). These phase differences are converted into corresponding variations of the width of the phase detector plate current pulses. The output of phase detector V107 is applied to cathode follower V108A through L112. The network, consisting of L112, C136, and C137, forms an rf filter to remove the 5 mc component from the output signal. The duty cycle of the pulses applied to the grid of V108A has an average voltage amplitude equal to the average phase difference between the reference and signal voltages.

b. Phase detector V107 can be considered as a constant current source, controlled by two on-off switches connected in series with the source. The two grids, pins 2 and 6, are the controlling switches, and the plate current of V107 is the constant current source. The on-off switches (the grids of V107) are actuated by the 5 mc signal and reference pulses. V107 is normally biased so that a 90 degree phase difference between the signal and reference input signals results in a plate current pulse. The width of this pulse lies midway between the plate current pulse width resulting from a zero degree phase difference, and zero plate current representing a 180 degree phase difference. The plate current pulses from V107 have a duty cycle corresponding to the average phase difference between the input and reference signals. Thus, these pulses have an average amplitude proportional to the average phase difference between the two signals. Potentiometer R138, in the cathode circuit of V107, permits the bias of this tube to be set so that a 90 degree phase difference produces a plate current pulse width that is the 50% point of the pulse width variations. Potentiometer R138, the SYMMETRY ADJ control, is adjusted so that the plate current

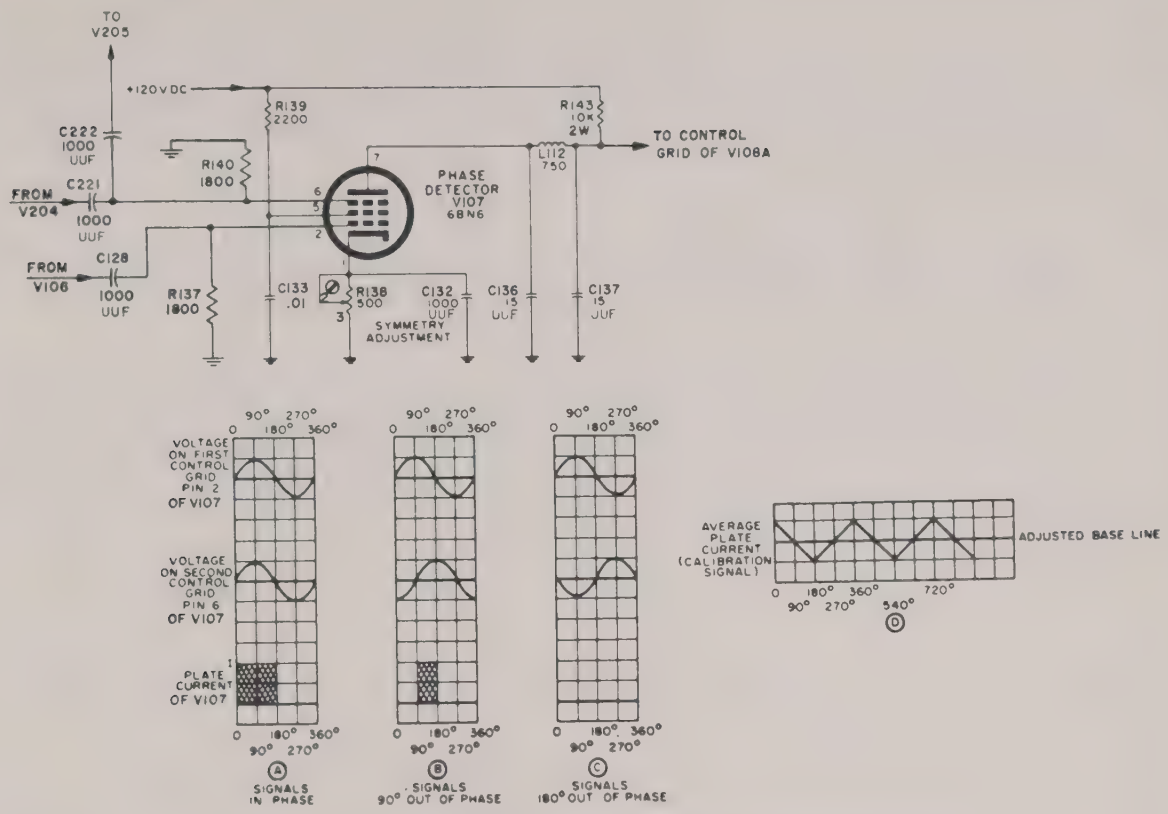


Figure 2-13. Phase Detector Stage, Simplified Schematic Diagram

that flows through V107 when the signals are either 90 degrees or 270 degrees out of phase is the same as the plate current flowing in the absence of signal inputs.

2-19. SERIES STRING REGULATED FILAMENTS (See figure 2-14.)

a. Six tubes (V103, V203, V314, V317, V404, and V408), with series dropping resistor R552, comprise the series string circuit for the regulated filaments. R552 limits the current through the series string to the correct nominal value. Since the power supplies are fully regulated to close limits, the filament supply for these tubes is held to the same regulation. This avoids the need for a complex regulated filament supply.

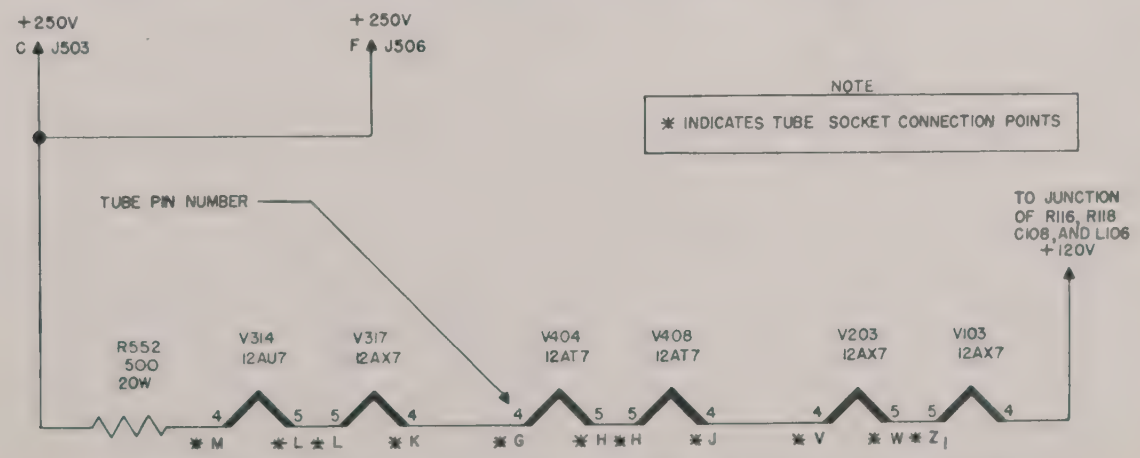

+250V C J503
+250V F J506
NOTE
* INDICATES TUBE SOCKET CONNECTION POINTS
TUBE PIN NUMBER
TO JUNCTION OF R116, R118 C108, AND L106 +120V
R552 500 20W
V314 12AU7
V317 12AX7
V404 12AT7
V408 12AT7
V203 12AX7
V103 12AX7
4 5 5 4 4 5 5 4 4 5 5 4
*M *L *L *K *G *H *H *J *V *W *Z1

Figure 2-14. Series String Regulated Filament Circuit, Simplified Schematic Diagram

b. Between the +250 volt and +120 volt points, there is a difference potential of +130 volts. Six of the more critical tubes, whose circuits require close regulation of tube performance, have their filaments connected in series. Together with a suitable series dropping resistor, they require +130 volts for proper operation. Since both the +250 volt and the +120 volt supplies are fully regulated, the filaments of these tubes will be held very close to the nominal operating voltages.

2-20. HOLD (BOXCAR) CIRCUIT (See figure 2-15.)

a. General. The additional circuits used to measure large absolute jitter, and disturbance frequency and waveforms, consist of a group of conventional phantastron generators, and a hold (boxcar) circuit. The latter circuit is analyzed below.

b. Analysis. With no signal, the grid currents, caused by the positive sampling triggers, develop negative bias across R366 and R367. The voltage developed across these resistors is stored by capacitors C334 and C336, respectively, resulting in cutoff of both sections of V316. When the sampling trigger pulse is applied to T302 from pulse transformer T301, positive pulses are applied to the grids of V316, and both sections of the tube conduct. The signal voltage at the cathode of V316B is thus applied to C333, charging it to the same potential. When the sampling trigger is removed, C333 stores the signal until the next sampling trigger. This voltage is applied to V314B, whose output is applied to the video circuits for display on the CRT.

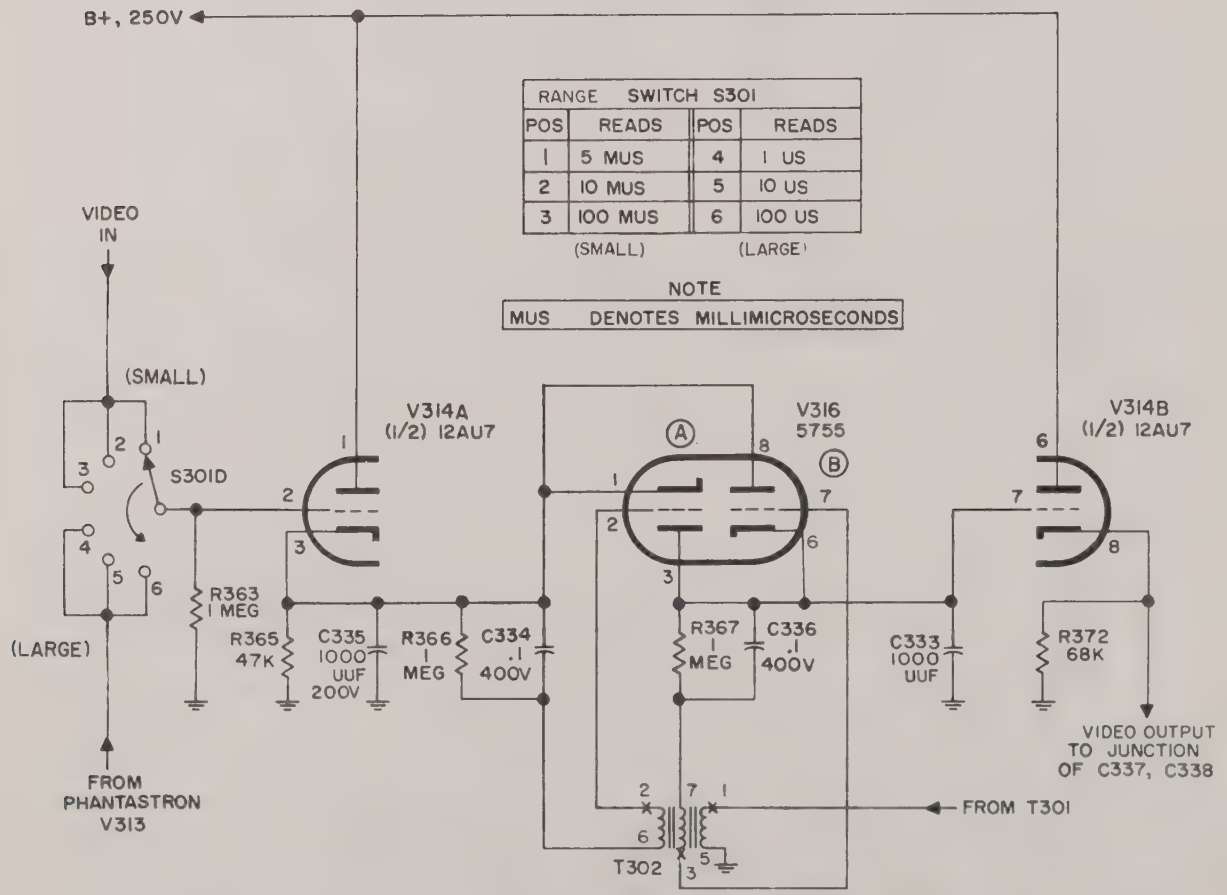


Figure 2-15. Hold (Boxcar) Circuit, Simplified Schematic Diagram

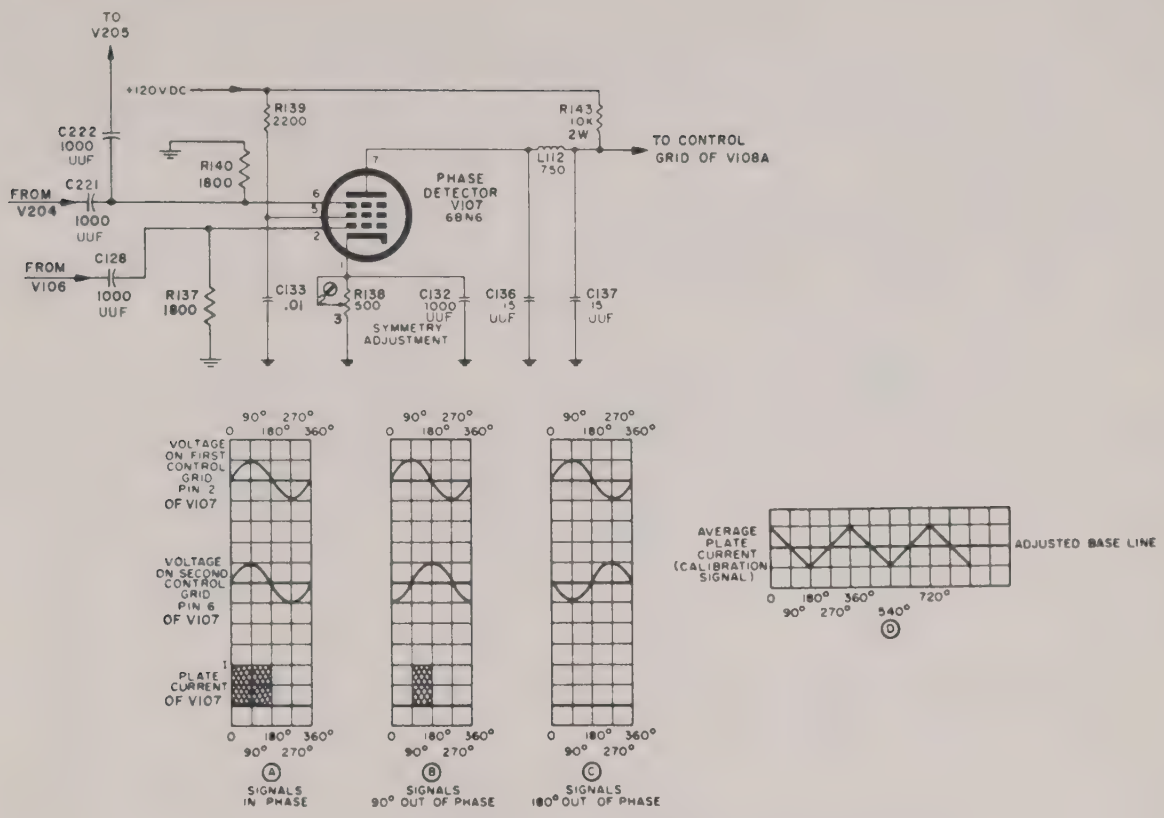


Figure 2-13. Phase Detector Stage, Simplified Schematic Diagram

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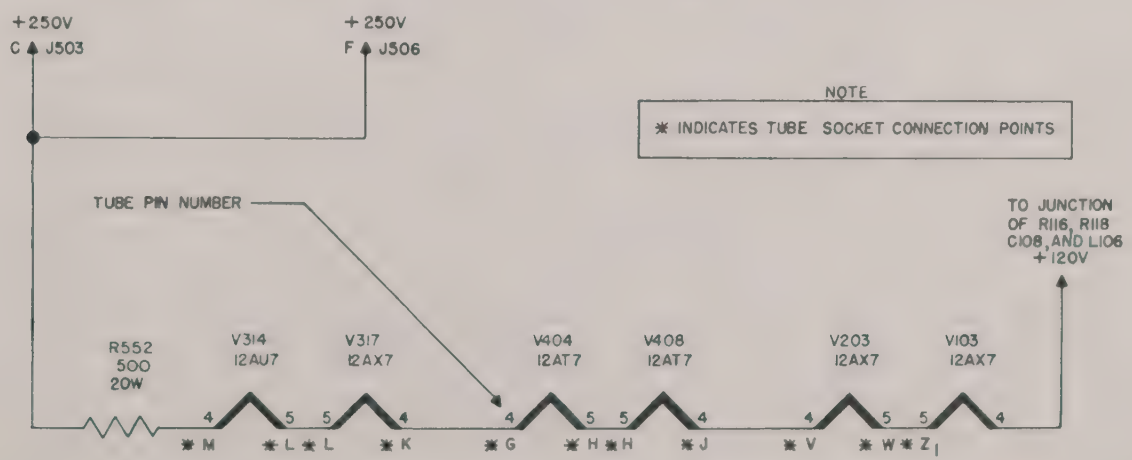

Figure 2-14. Series String Regulated Filament Circuit, Simplified Schematic Diagram

b. Between the +250 volt and +120 volt points, there is a difference potential of +130 volts. Six of the more critical tubes, whose circuits require close regulation of tube performance, have their filaments connected in series. Together with a suitable series dropping resistor, they require +130 volts for proper operation. Since both the +250 volt and the +120 volt supplies are fully regulated, the filaments of these tubes will be held very close to the nominal operating voltages.

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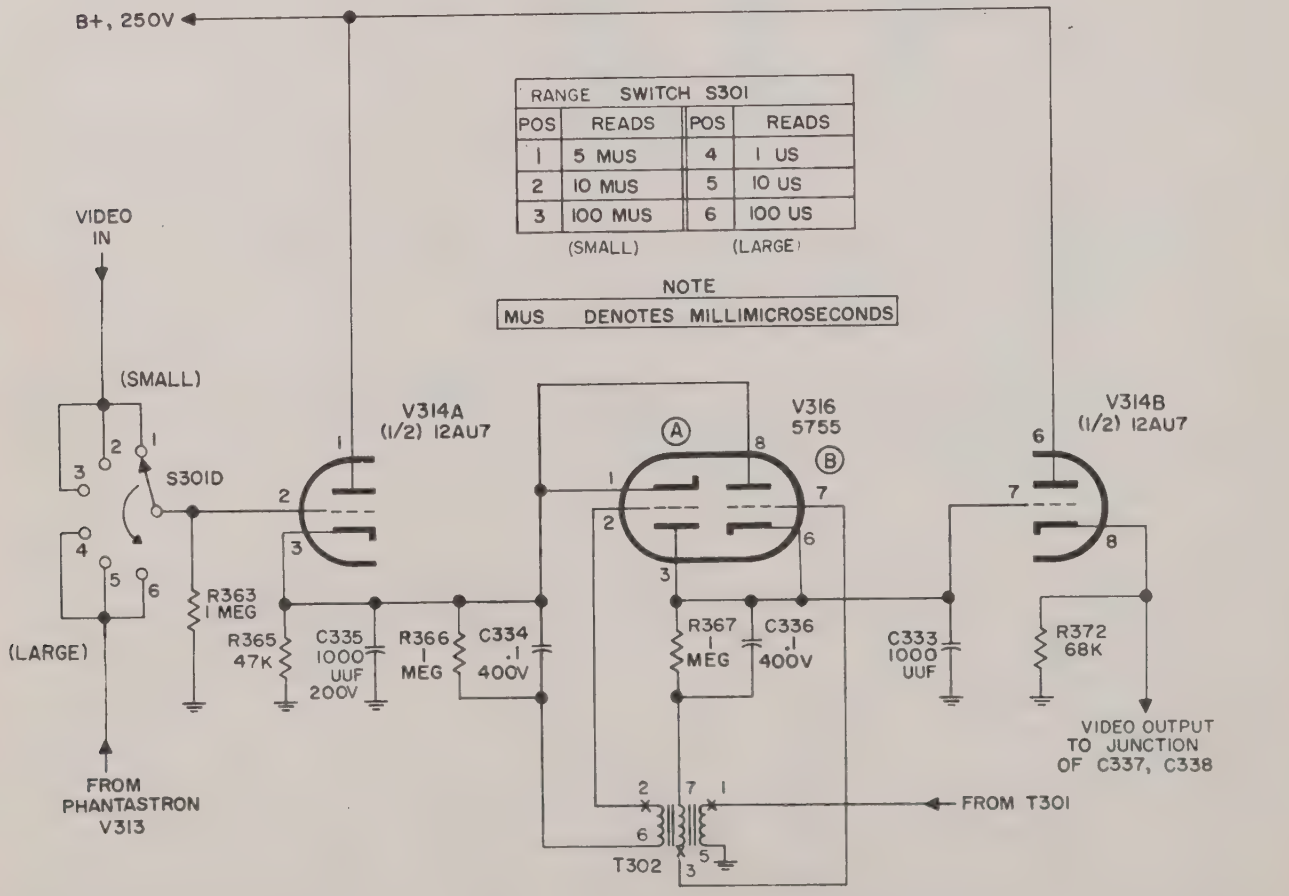


Figure 2-15. Hold (Boxcar) Circuit, Simplified Schematic Diagram

SECTION 3
OPERATION

3-1. CONTROLS AND FUNCTIONS

The table below lists the front panel controls, switches, connectors and indicators, and gives their respective functions. Figure 3-1 shows their locations.

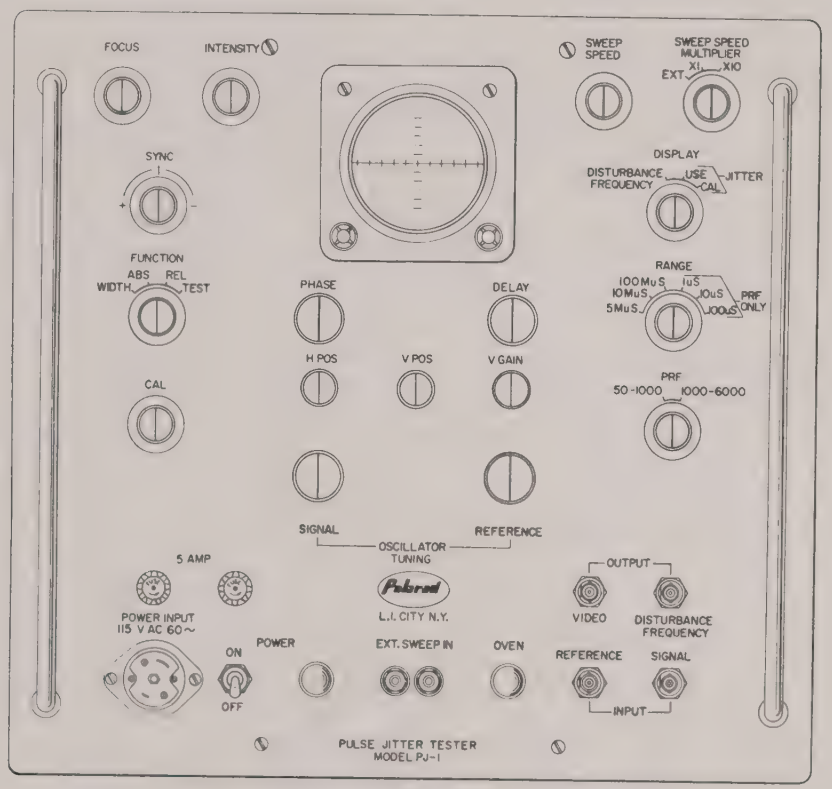


Figure 3-1. Model PJ-1 Pulse Jitter Tester, Front Panel View

Table 3-1. Operating Controls and Connectors

Control or Connector	Function
POWER INPUT	Connects ac line plug to equipment.
ON-OFF	Applies ac power to equipment.
POWER indicator	Indicates application of ac power to equipment.
EXT. SWEEP IN	Two jacks which accept an audio oscillator signal for application to the horizontal video amplifiers; the resultant Lissajous pattern enables measurement of disturbance frequency.
OVEN indicator	Cycles on and off when 5 mc crystal has reached proper operating temperature (approximately 10 minutes warmup).
REFERENCE INPUT	Accepts reference signal for relative jitter measurement.

Table 3-1. Operating Controls and Connectors (Continued)

Control or Connector	Function
SIGNAL INPUT	Accepts input signal for all types of jitter measurement.
VIDEO OUTPUT	Provides video output signal to an external oscilloscope for measurement or display.
DISTURBANCE FREQUENCY OUTPUT	Provides disturbance frequency signal to an external oscilloscope for measurement or display.
PRF	Switches equipment to PRF range within which the PRF of incoming signal falls.
RANGE	Switches to appropriate calibration range for jitter measurement (the luS, 10uS, and 100uS positions are used in Large Absolute Jitter and Disturbance Frequency Measurements only).
DISPLAY	A 3-position switch: DISTURBANCE FREQUENCY position is used for disturbance frequency measurement; USE position is used for all other types of jitter measurement; CAL position is used as a preliminary step in Large Absolute Jitter measurement.
SWEEP SPEED	Adjusts sweep speed of Sweep Phantastron (V309A, V311) to sweep rate of input signal. (Used in Disturbance Frequency Measurements only).
SWEEP SPEED MULTIPLIER	Varies sweep speed by a factor of X1 or X10; EXT position is used when External Sweep Input is desired.
FOCUS	Adjusts sharpness of lines on CRT screen.
INTENSITY	Adjusts brightness of display on CRT screen.
SYNC	Locks in display on CRT screen for observation of Disturbance Frequency pattern.
FUNCTION	Selects type of jitter to be measured; in TEST position, permits pre-calibration of instrument.
CAL	Adjusts height of display to fill the 10 vertical division lines on CRT screen; used for all measurements except DISTURBANCE FREQUENCY.
V GAIN	Adjusts height of display on CRT screen for Disturbance Frequency measurement.
V POS	Centers display vertically on CRT screen.
H POS	Centers display horizontally on CRT screen.
PHASE	Adjusts phase angle of signals on CRT display for measurement of residual, relative and width jitter.
DELAY	Adjusts CRT display for Large Absolute Jitter measurement only (with DISPLAY switch in CAL position).
SIGNAL OSCILLATOR TUNING	Adjusts signal oscillator frequency to obtain proper display on CRT screen.
REFERENCE OSCILLATOR TUNING	Adjusts 5 mc crystal oscillator frequency to obtain proper display on CRT screen; (used for Small Absolute Jitter measurements only).

3-2. PRELIMINARY OPERATING PROCEDURE

a. Operation of the Pulse Jitter Tester follows a straightforward procedure, and requires only normal safety precautions. Do not operate the instrument outside of its case, unless servicing or maintenance is required. Dangerous circuit voltages are present, which could cause serious injury or death.

b. Place the instrument on the work bench or in its operational area. Plug in the ac line cord, and turn the ON-OFF switch to ON. The POWER indicating lamp should light. Wait approximately ten minutes, until the OVEN pilot light begins to cycle on and off at regular intervals, which indicates that the instrument has reached a stable operating temperature and is ready for use.

3-3. PRE-CALIBRATION PROCEDURE FOR ALL JITTER MEASUREMENTS

a. Signal Connections. Signal connections to be made to the equipment are given below:

(1) For Relative Jitter. Apply the pulse signal to the SIGNAL INPUT jack, and connect the pulse reference signal to the REFERENCE INPUT jack.

(2) For Residual, Width and Absolute Jitter. Apply the pulse signal to the SIGNAL INPUT jack only.

b. After making signal connections, proceed as follows for small (5, 10, or 100MuS) pulse jitter measurements:

(1) Set the FUNCTION switch to TEST position.

(2) Set the DISPLAY switch to USE position.

(3) Set the RANGE switch to 100MuS position.

(4) Use H POS and V POS controls to center display.

(5) Use FOCUS and INTENSITY controls to improve display.

(6) Adjust SIGNAL OSCILLATOR TUNING control to obtain approximately one sine wave cycle on CRT screen (see figure 3-2A).

(7) Adjust CAL control so that the peak-to-peak amplitude of the waveform just fills the space between the extreme vertical graticule lines (figure 3-2A).

(8) Adjust the V POS and H POS controls to re-center the pattern while the CAL control is being adjusted. (After the amplitude has been correctly set, DO NOT USE THESE CONTROLS FURTHER, except where specifically instructed.)

(9) Vary the SIGNAL OSCILLATOR TUNING control to obtain zero beat (a horizontal line) across the CRT screen. (See figure 3-2B.)

(10) Adjust PHASE CONTROL to re-center TRACE, and re-adjust SIGNAL OSCILLATOR TUNING control, if necessary.

3-4. MEASUREMENT OF JITTER (See figure 3-2C.)

a. Residual Jitter. The residual level of jitter within the equipment should be determined before making other measurements. If the residual jitter exceeds 0.5 millimicrosecond, the instrument must be checked and repaired before accurate pulse jitter measurements can be made.

NOTE

Each jitter measurement that follows begins with step 11, continuing from step 10, above.

(11) Switch the RANGE selector to the 10MuS position, and re-center the display with the PHASE control, if necessary.

(12) Switch the RANGE selector to the 5MuS position. Re-center the display with the PHASE and SIGNAL OSCILLATOR TUNING controls, if necessary. The residual jitter can now be measured.

NOTE

When the RANGE selector is set to the 5MuS position, each vertical graticule division on the CRT screen represents 0.5 millimicrosecond. The residual jitter in the instrument should not exceed 0.5 millimicrosecond (one-half division above and below the horizontal center line.)

b. Relative Jitter.

(11) Connect the pulse reference signal to the REFERENCE INPUT jack.

(12) Set the FUNCTION selector to REL, and the RANGE selector to 100MuS.

(13) Adjust the SIGNAL OSCILLATOR TUNING control, if necessary, for exact zero beat (figure 3-2B).

(14) Adjust the PHASE control to center the CRT display.

(15) Set the RANGE selector to the 10MuS or 5MuS position. Re-adjust the PHASE and SIGNAL OSCILLATOR TUNING controls, if necessary, and then measure the jitter, in millimicroseconds, as displayed on the CRT screen.

c. Width Jitter.

Note. No reference input signal is required.

(11) Set the FUNCTION selector to WIDTH, and the RANGE selector to 100MuS.

(12) Adjust the SIGNAL OSCILLATOR TUNING control, if necessary, for exact zero beat (figure 3-2B).

(13) Adjust the PHASE control to center the CRT display.

(14) Set the RANGE selector to the 10MuS or 5MuS position. Re-adjust the PHASE and SIGNAL OSCILLATOR TUNING controls, if necessary, and then measure the jitter, in millimicroseconds, as displayed on the CRT screen.

d. Small Absolute Jitter.

(11) Set the FUNCTION selector to ABS, and the RANGE selector to 100MuS. A sine wave envelope will appear on the CRT screen, as in figure 3-2D.

(12) Rotate the SIGNAL OSCILLATOR TUNING control until the display falls into parallel lines, as in figure 3-2E.

(13) Back off the SIGNAL OSCILLATOR TUNING control to the point where the parallel lines return to the sine wave envelope.

(14) Adjust the CAL control until the display just fills the space between the extreme vertical graticule lines.

(15) Adjust the SIGNAL OSCILLATOR TUNING control for parallel lines.

(16) Adjust the REFERENCE OSCILLATOR TUNING control for zero beat. Touch up the SIGNAL OSCILLATOR TUNING control, if necessary.

(17) Set the RANGE selector to the 10MuS or 5MuS position, and then measure the small absolute jitter, in millimicroseconds, as displayed on the CRT screen. Center the display, if necessary, with the V POS control.

e. Large Absolute Jitter.

NOTE

When the RANGE selector is set to the large ranges, large absolute jitter and disturbance frequency are the only measurements that can be made. In the 1, 10 and 100uS positions of the RANGE selector, the FUNCTION selector is inoperative, but should be left in TEST position.

(11) Set the FUNCTION selector to TEST, and the RANGE selector to 100uS.

(12) Set the DISPLAY selector to CAL.

(13) Set the PRF switch to the appropriate PRF range for the input pulse.

(14) Rotate the DELAY control to its maximum counterclockwise position.

(15) Center the CRT display, using the V POS control only.

(16) Rotate the DELAY control slowly clockwise until a sawtooth waveform appears on the CRT screen. Position the sawtooth as shown in figure 3-2F.

NOTE

While the DELAY control is being adjusted, various waveforms may appear on the CRT. Ensure that the waveform used corresponds to figure 3-2F. Do not touch the DELAY control further. Re-center the display with the V POS control, if necessary.

(17) Set the DISPLAY selector to the USE position.

(18) Re-center the display, using the V POS control only.

(19) Measure the large absolute jitter, in microseconds, as displayed on the CRT screen.

(20) If the jitter cannot be measured accurately in the 100uS position, set the DISPLAY switch on CAL, switch the RANGE to either 10uS or luS, and repeat steps 14 through 19.

3-5. OBSERVATION AND MEASUREMENT OF DISTURBANCE FREQUENCY

a. Waveforms.

(1) Before the jitter disturbance waveform can be observed, the equipment must be set up for the proper jitter measurement.

(2) Set the DISPLAY selector to the DISTURBANCE FREQUENCY position.

(3) Set the RANGE selector to the appropriate uS position.

(4) Set the SWEEP SPEED MULTIPLIER switch to the Xl or X10 position, and vary the SWEEP SPEED and SYNC controls to obtain a stable disturbance waveform on the CRT screen. (See figure 3-2G.)

b. Frequency Measurement.

(1) Before the jitter disturbance frequency can be measured, the equipment must be set up for the proper jitter measurement.

(2) Set the DISPLAY selector to the DISTURBANCE FREQUENCY position.

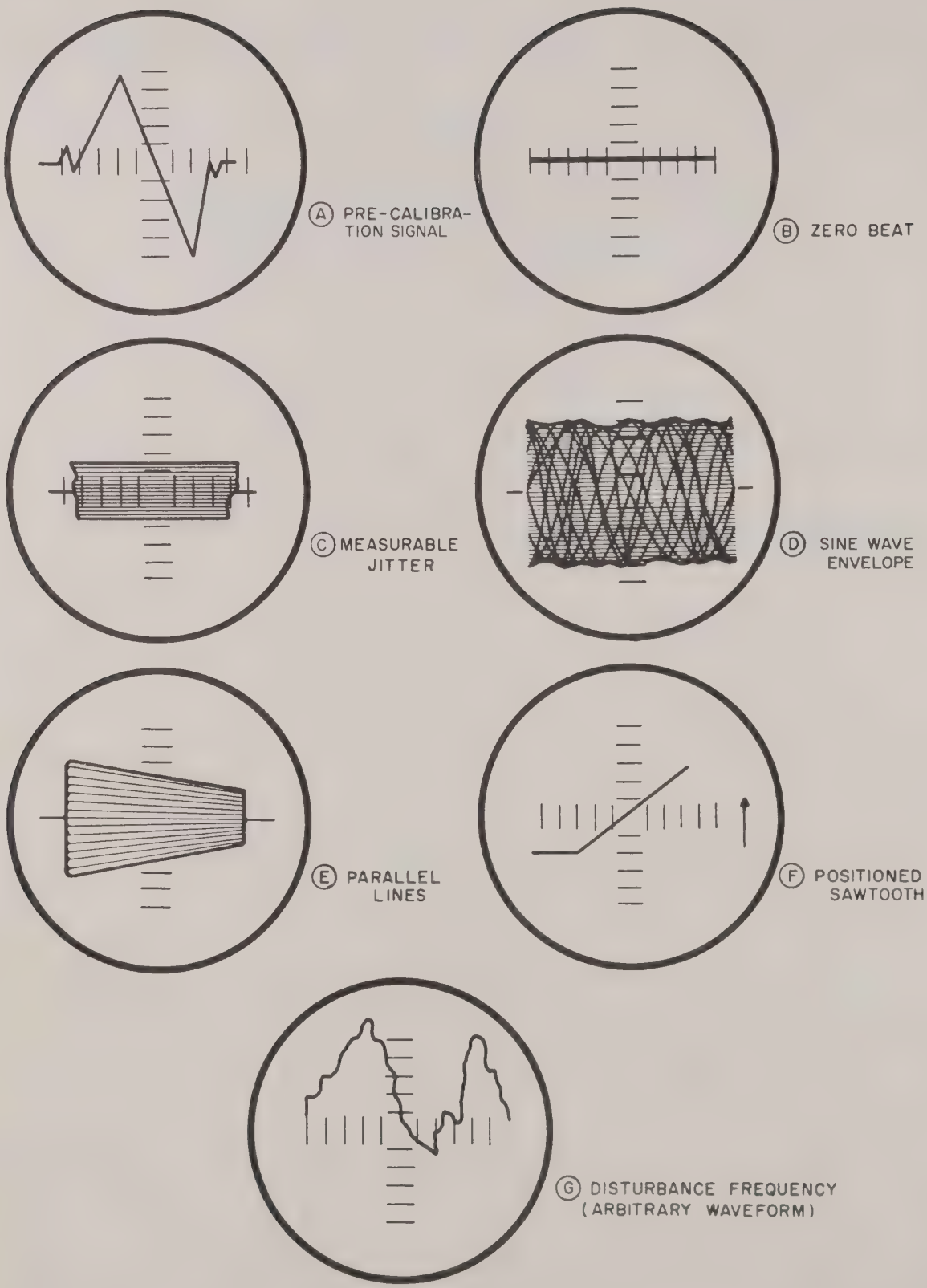


Figure 3-2. Typical Waveforms

(3) Set the SWEEP SPEED MULTIPLIER selector to the EXT position, and apply the output from an audio oscillator to the EXT. SWEEP IN jacks.

(4) Vary the V GAIN control for proper height of display.

(5) Set the audio oscillator frequency to the approximate frequency of the jitter disturbance. Then slowly adjust the audio oscillator frequency until the lowest ratio Lissajous pattern is displayed on the CRT screen.

(6) Determine the frequency in the conventional manner from the observed Lissajous figure.

SECTION 4
MAINTENANCE

WARNING
DANGEROUS VOLTAGES ARE PRESENT WHEN THE EQUIPMENT IS IN OPERATION.

4-1. GENERAL

Servicing this equipment will present no special difficulties if a logical and straightforward approach is used. Certain key signals are to be used as the basis for isolating troubles to a particular printed board, and within a board to a particular circuit or circuits.

4-2. MAJOR ASSEMBLIES

The instrument consists of five major units:

a. The chassis and frame assembly contains the major components in the power supply group. The frame assembly serves as a mount for the four printed boards, the CRT mount and shield, and such components as are not mounted on the main chassis and front panel. These boards are designated:

(1) Board No. 1 - Signal Strip;
(2) Board No. 2 - Reference Strip;
(3) Board No. 3 - Output and Display;
(4) Board No. 4 - Input.

WARNING
When working in the vicinity of the blower motor, do not allow tools or fingers to come into contact with the blower fan blades.

b. Board No. 1 and board No. 2 are the center boards, and are readily removed for service, as described in paragraph 4-5. A test cable is furnished with the equipment so that either of the two center boards can be operated, and tests made under normal operating conditions, when the board is removed from the equipment.

4-3. BASIC TEST POINTS

The basic block diagrams (figures 2-5 to 2-9) provide a rapid means of isolating troubles to the malfunctioning circuit. The indicated voltage readings on the schematics are to be considered as a guide and, unless otherwise indicated, represent average readings. Some minor variations, from one model to another, are to be expected. In general, ±10% of indicated values should be considered as normal.

4-4. TEST PROCEDURES

a. No special test procedures are required, other than checking for the proper signal voltages, as in any normal maintenance procedure. The equipment required for maintenance work consists essentially of a sensitive, wideband oscilloscope, and a VTVM.

b. Although no special methods are required for servicing, the following procedure is suggested as a rapid means for isolating any malfunction to a particular board. Standard trouble-shooting techniques will serve to locate the particular part or parts that are defective.

(1) Power Supply. (See figure 6-4.) Check for normal power supply voltages, as indicated on the diagram. These voltages can be readily measured at test socket J509. These voltages are not critical and can vary ±10%. However, if the power supply is suspected of being faulty, the percentage of regulation should be checked. The regulation should be better than ±1%. In most cases, the regulation change will be sufficiently small to be unreadable on a conventional multimeter. No power supply adjustments are normally made. If all supply voltages are normal, proceed to step (2).

(2) Input Board. (See figures 4-2 and 6-1.) Check for the presence of input signals at capacitors C401 and V424. Check for the presence of output signals at resistors R427 and R466. These pulses should be of positive polarity. Because of the varying nature of the waveforms of the input signals, the resultant waveform of the signal (as read at various points of the input board circuit) and the output signal from the input board will vary. For this reason, typical waveforms are not given. Before removing or replacing parts on any of the printed boards, refer to paragraph 4-5, Printed Board Precautions.

(3) Signal Board. (See figures 4-3 and 6-2.) Check at the grid, pin 2, of V103A for the presence of a pulse from gated multivibrator V102; this pulse should be approximately 100 microseconds wide. Check at the grid, pin 2, of V104A for the presence of a pulse of 5 mc rf; this pulse should also be approximately 100 microseconds wide.

NOTE

When this instrument fails to function properly, reference should be made to Section 2 and the type of measurement being made. Since the type of measurement in use determines the circuitry employed, the trouble-shooting procedure undertaken should be concerned only with those circuits employed for a particular measurement.

Before checking the phase detector, disconnect the short cable connecting J103 to J201. Then check for output at the grid, pin 7, of V108A. The last check of the signal strip is to determine whether an output signal is present at the cathodes of V108A and V108B.

(4) Reference Board. (See figures 4-4 and 6-2.)

(a) When making relative and width jitter measurements, only those portions of the reference board circuitry consisting of V201 through V204 are employed. The portions of the circuitry from V205 through V207 have their plate voltage supply disconnected, and do not function during the above measurements. For checking V201, V202, and V203 circuitry, the same procedure as used for the signal board is employed. (See subparagraph 3, above.) The output of V204 is checked at J201. When absolute jitter is being measured, the plate supply voltage to V201 through V204 is disconnected and these circuits do not function.

(b) For the absolute jitter measurement, the circuitry using V205 through V207 is employed. The salient check points for this circuitry consist of the output of V205 (checked at J201) and the cycling of the 5 mc crystal oscillator oven. The OVEN pilot indicator lamp should continuously cycle. If the lamp remains off or stays on, the oven control is faulty and must be checked. If the zero-beat line cannot be locked in, when making the absolute jitter measurement, then the afc control circuit is not functioning and should be checked.

(5) Output and Display Board. (See figures 4-5 and 6-3.)

(a) When the instrument is set up for making the small disturbance frequency measurement, only those circuits indicated in figure 2-5, plus the display circuits, are employed. The balance of the circuitry on this board is not used for this measurement. The video amplifier and display circuits are employed for all the measurements made. A key check point for this circuitry is pin 3 of V314A (which checks for video output of V314A). Also, since all the phantastron and blocking oscillators are normally not free-running, the failure of V308A to function may indicate trouble in the initiating phantastron, or in the preceding trigger amplifier, V301.

(b) In the circuits used for large disturbance frequency measurement, the entire phantastron and blocking oscillator circuitry is employed. When trouble-shooting this section of the board, the entire circuitry

must be checked. (See figures 2-6, 4-4, and 6-3.) The video and display circuits are of conventional design and do not require any special discussion. Standard trouble-shooting techniques apply.

4-5. REMOVAL OF PRINTED BOARDS (See figures 4-1 through 4-5.)

a. Input Board.

(1) Remove FUNCTION knob from front panel.

(2) Disconnect jack J510, at top front of board.

(3) Loosen both nylon couplings on front section of FUNCTION selector shaft (behind front panel).

(4) Remove the shaft front section, including the nylon couplings.

* (5) Remove the three mounting brackets (at top front, bottom front, and top rear of board) by removing two mounting screws from each.

** Remove the four mounting brackets located at the corners of the board, by removing the two mounting screws from each.

* (6) Lift the board upward carefully, until plug P401, located at bottom left rear of board, is completely disengaged.

** Disconnect plug P401, located at bottom left rear of board.

(7) Tilt board inward gradually, and remove through side of equipment frame.

b. Signal Board.

(1) Remove PHASE and SIGNAL OSCILLATOR TUNING knobs from front panel.

(2) Ensure that SIGNAL OSCILLATOR TUNING capacitor C113, located on rear of SIGNAL OSCILLATOR TUNING shaft, is fully meshed.

(3) Remove V504 and V512.

(4) Unlock the two snap fasteners (at top rear and bottom rear of board).

* (5) Remove holding screw from mounting bracket at top front of board.

** Remove holding screws from mounting brackets at top front and bottom front of board.

(6) Disconnect interconnecting cable, located at top right center of board.

** (6A) Disconnect plug P101, located at top front of board.

(7) Gently disengage board from the snap fasteners, and withdraw board straight back through rear of equipment frame.

CAUTION

The plates of C113 must be fully meshed, or they will strike tube sockets as the board is withdrawn, and the capacitor may be damaged.

* Serial numbers up to 116.
** Serial numbers 117 and higher.

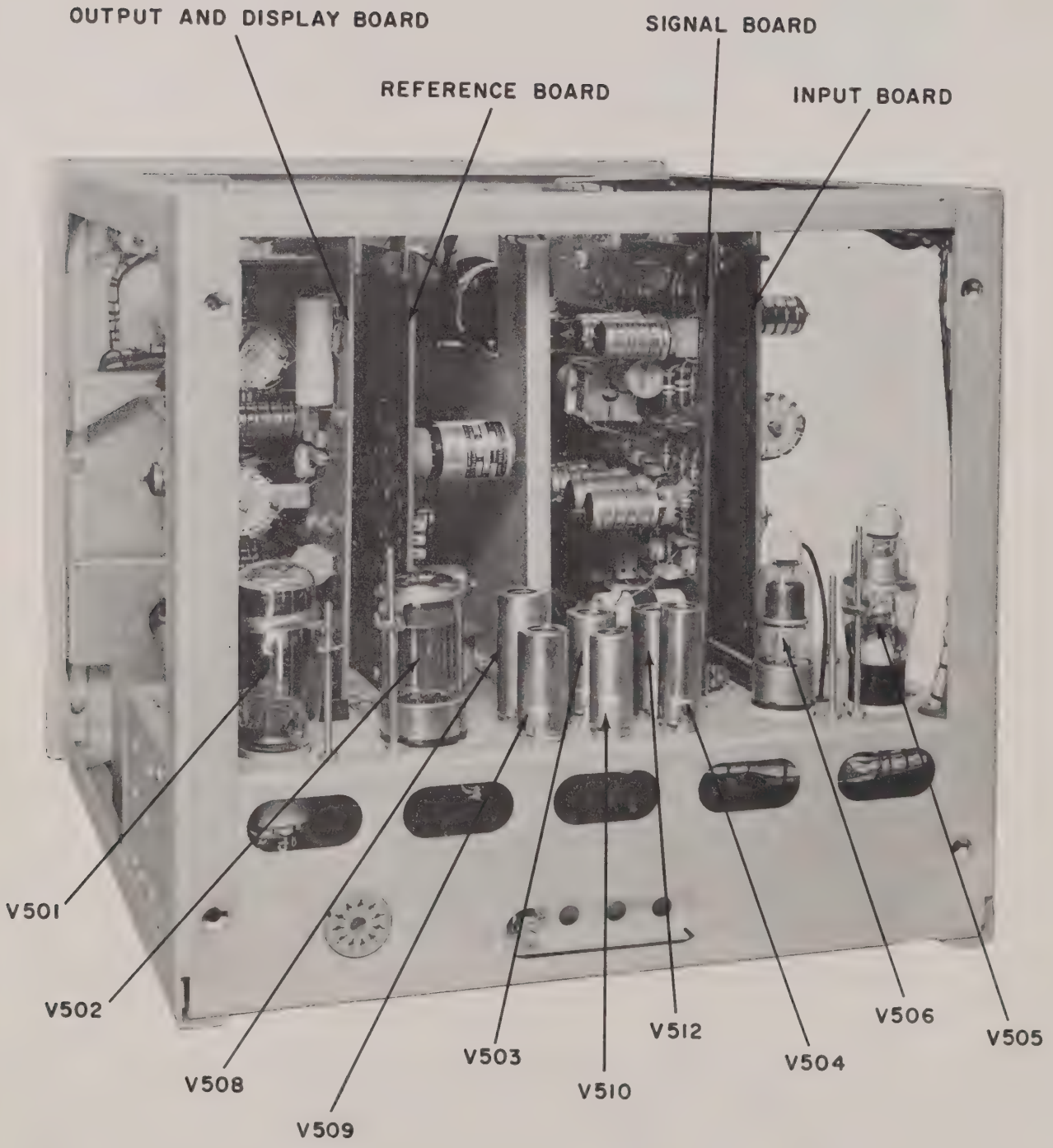


Figure 4-1. Model PJ-1 Pulse Jitter Tester, Rear View, Showing Board Locations and Power Supply Tube Locations

c. Reference Board.

(1) Remove REFERENCE OSCILLATOR TUNING knob from front panel.

(2) Ensure that REFERENCE OSCILLATOR TUNING capacitor C236, located on rear of REFERENCE OSCILLATOR TUNING shaft, is fully meshed.

(3) Remove V502, V508 and V509.

(4) Unlock the two snap fasteners (at top rear and bottom rear of board).

* (5) Remove holding screw from mounting bracket at top front of board.

** Remove holding screws from mounting brackets at top front and bottom front of board.

(6) Disconnect interconnecting cable, located at top left center of board.

** (6A) Disconnect plug P201, located at top front of board.

(7) Gently disengage board from the snap fasteners, and withdraw board straight back through rear of equipment frame.

CAUTION

The plates of C236 must be fully meshed, or they will strike tube sockets as the board is withdrawn, and the capacitor may be damaged.

d. Output and Display Board.

(1) Remove DISPLAY, RANGE, and PRF knobs from the front panel.

(2) Disconnect Winchester plug P302, located at top front of board, and disconnect jack J301, which connects to CRT socket.

(3) Loosen both nylon couplings on the front section of each of the three switch shafts (behind the front panel).

(4) Remove each shaft front section, including the nylon couplings.

* (5) Remove the three mounting brackets (at top front, bottom front, and top rear of board) by removing two mounting screws from each.

** Remove the four mounting brackets, located at the four corners of the board.

* (6) Lift the board upward carefully, until plug P301, located at bottom right rear of board, is completely disengaged.

** Disconnect plug P301, located at bottom right rear of board.

(7) Tilt board inward gradually, and remove through side of equipment frame.

4-6. REPLACEMENT OF PRINTED BOARDS

a. Input Board.

(1) Insert board through side of frame, and tilt it gradually into position.

* Serial numbers up to 116.
** Serial numbers 117 and higher.

* (2) Lower board carefully, until plug P401, located at bottom left rear of board, is completely engaged.

** Reconnect plug P401, located at bottom left rear of board.

(3) Replace shaft front section, and fasten nylon couplings loosely.

(4) Replace all clamps at corners of board. Fasten screws loosely.

CAUTION

Insulation strips are provided to prevent shorting between the mounting brackets and the printed board. Ensure that the insulation strips are replaced properly.

(5) Tighten nylon couplings, and replace front panel FUNCTION knob.

(6) Tighten bracket screws gradually, ensuring that FUNCTION knob does not bind. The board may have to be shifted slightly.

(7) Turn FUNCTION switch fully left, and align pointer to WIDTH position. Retighten holding screw.

(8) Reconnect jack J510, located at top front of board.

b. Signal Board.

Reverse the removal procedure of Section 4-5b. Ensure that plugs and jacks mate properly.

c. Reference Board.

Reverse the removal procedure of Section 4-5c. Ensure that plugs and jacks mate properly.

d. Output and Display Board.

(1) Insert board through side of frame, and tilt it gradually into position.

* (2) Lower board carefully, until plug P301, located at bottom right rear of board, is completely engaged.

** Reconnect plug P301, located at bottom right rear of board.

(3) Replace each shaft front section, and fasten nylon couplings loosely.

(4) Replace all clamps at corners of board. Fasten screws loosely.

CAUTION

Replace insulation strips between brackets and board exactly as before removal.

(5) Tighten nylon couplings. Replace the three front panel knobs.

(6) Tighten bracket screws gradually, ensuring that the three knobs do not bind. The board may have to be shifted slightly.

(7) Turn each knob fully left, and align pointers with their proper front panel marks. Retighten holding screws.

(8) Reconnect Winchester plug P302, located at top front of board, and reconnect jack J301, which connects to CRT socket.

* Serial numbers up to 116.
** Serial numbers 117 and higher.

4-7. PRINTED BOARD PRECAUTIONS

If it is necessary to replace any components mounted on the printed boards, a few precautions should be noted before proceeding with replacement:

a. Care must be exercised when removing parts, to avoid unnecessary physical contact with the printed wires on the board.

b. Care must be exercised not to scratch or press down on the printed wiring; failure to observe this precaution may result in an open circuit and subsequent circuit failure.

c. When soldering replacement parts into the wiring, a low-temperature solder is recommended, in order to prevent burning of the board material, or possible separation of the printed wiring from the base material.

CAUTION

Under no circumstances should acid core solder be used on any part of the printed board wiring. Failure to observe this warning will result in damage to the board and wiring; short circuits and circuit failure will follow. When using test equipment prods with sharp points, exercise extreme care not to damage the printed wiring.

d. Do not use excess solder, as this may result in solder flow to adjacent wiring, producing short circuits. Because of the close spacing of printed wires, these short circuits may be difficult or impossible to clear.

e. Solder only to the eyelet or rivet solder points provided. Failure to observe this precaution may result in short circuits and circuit failure.

4-8. INITIAL ADJUSTMENTS AND CALIBRATIONS

a. Whenever the instrument is repaired or checked, there are adjustments that should be checked and readjusted, if necessary.

b. Signal Balance Adjustment. (See figures 4-2 and 6-1.)

A 20,000 ohm-per volt multimeter is connected across Test Points (1) and (2) (available as test jacks on the input board); adjust SIG BAL ADJ potentiometer R421 for a zero d-c voltage difference, as indicated on the multimeter. This must be done without an input signal.

c. Reference Balance Adjustment. (See figures 4-2 and 6-1.)

Connect a 20,000 ohm-per-volt multimeter across Test Points 3 and 4 (available as test jacks on the input board) and adjust REF BAL ADJ potentiometer R459 for a zero d-c voltage difference, as indicated on the multimeter. This must be done without an input signal.

d. Symmetry Adjustment. (See figures 4-3 and 6-2.)

For the phase detector V107, set the RANGE selector to any one of the small jitter positions (5, 10, 100 millimicroseconds). Adjust SYMMETRY ADJ control R138 until the beat pattern (not locked in zero beat) is symmetrical about the CRT base line.

e. Crystal Oscillator Tuning Adjustment. (See figures 4-4 and 6-2.)

(1) Proceed with steps 1 through 13 of Section 3-4d. The sine wave envelope is present on the CRT.

(2) Set the front panel REFERENCE OSCILLATOR TUNING control for minimum capacity (plates unmeshed).

(3) Vary XTAL OSC TUNING capacitor C232 until the 5 mc crystal oscillator just starts to oscillate. This may be observed by noting the reappearance of the sine wave envelope.

f. Signal Oscillator Tuning Adjustment. (See figures 4-3 and 6-2.)

(1) Leave all controls at their previous settings, and set the front panel SIGNAL OSCILLATOR TUNING control to mid-point of its capacity.

(2) Adjust signal oscillator tuning range capacitor C110 for zero beat or parallel lines on the CRT display.

g. Reference Oscillator Tuning Adjustment. (See figures 4-5 and 6-2.)

(1) Leave all adjustments at their previous settings, and set the FUNCTION selector to the WIDTH position.

(2) Adjust reference channel oscillator tuning capacitor C213 for zero beat on the CRT display.

h. Horizontal Amplifier Control Adjustment. (See figures 4-5 and 6-3.)

(1) Perform the required steps for any type of small jitter measurement, through the adjustment for zero beat.

(2) Adjust H AMPL potentiometer R338 until the extraneous information, present at either side of the jitter display, just disappears from the CRT.

i. 1 Microsecond and 10 Microsecond Phantastron Adjustments. (See figures 4-5 and 6-3.)

For these adjustments, the following auxiliary equipment is required: a pulse generator, capable of being accurately time-modulated, and having a prf of 2,000 pps (such as the Polarad Model MP-1A, or equivalent), plus a wide band oscilloscope with an accurately calibrated time base.

(1) 1 microsecond adjustment procedure:

(a) Set the modulation source, within the pulse generator, to a sine wave rate of 100 cps or less.
(b) Set the pulse generator to approximately 2,000 pps.
(c) Connect the oscilloscope vertical input probe to either pin 6 or pin 7 of blocking oscillator V308A.
(d) Observe the width of the sampling trigger jitter on the wide band oscilloscope, and adjust the pulse generator modulation so that the observed jitter will be one microsecond in width.
(e) Adjust 1 USEC CAL capacitor C329 so that full-scale deflection is obtained on the Pulse Jitter Tester CRT display.

(2) 10 microseconds adjustment procedure:

Repeat the procedure outlined for the 1 microsecond adjustment, except that the jitter observed on the oscilloscope will be 10 microseconds in width, and 10 USEC CAL capacitor C328 is adjusted for full-scale deflection on the Pulse Jitter Tester CRT display.

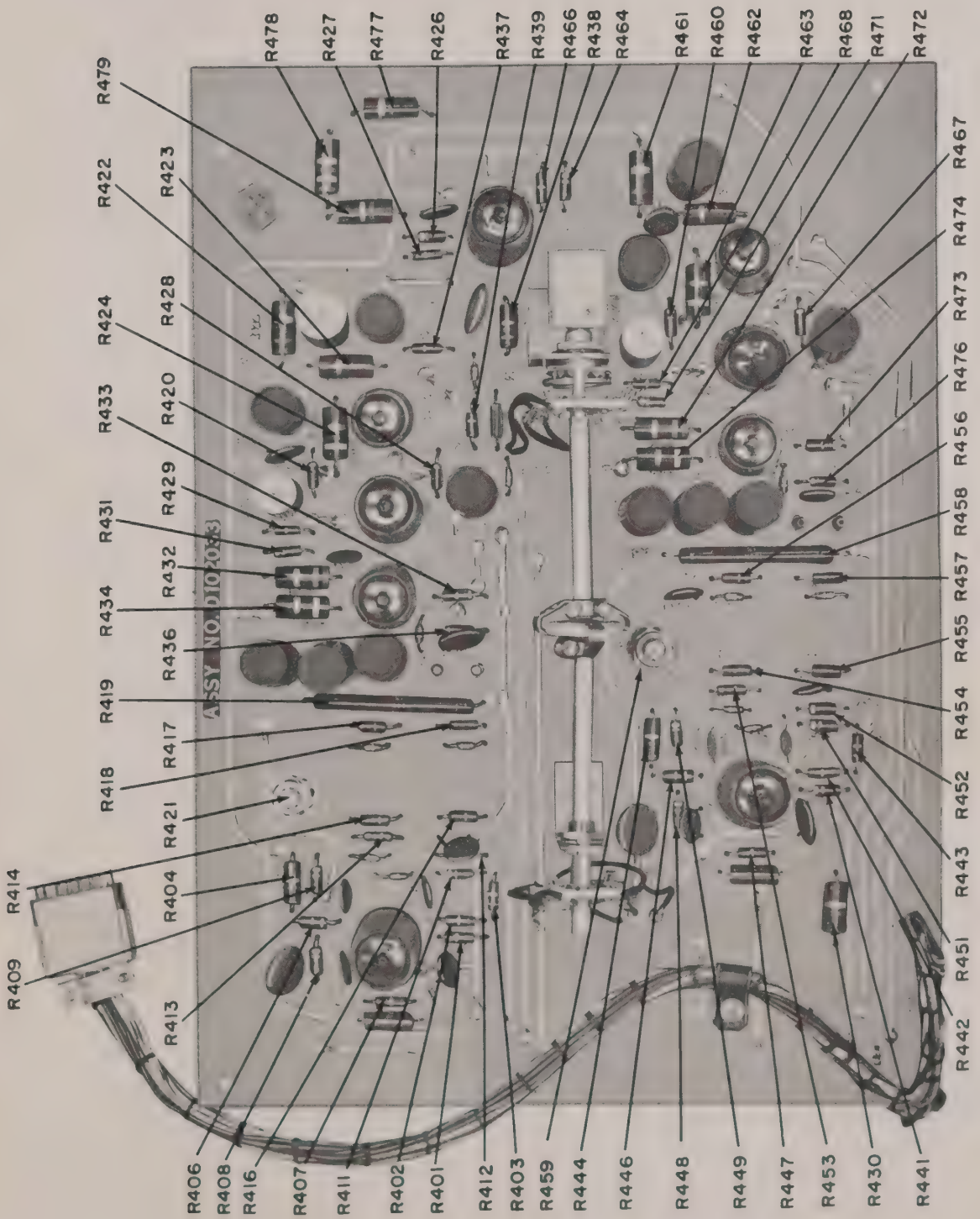


Figure 4-2. Input Board, Component Location (page 1 of 3)

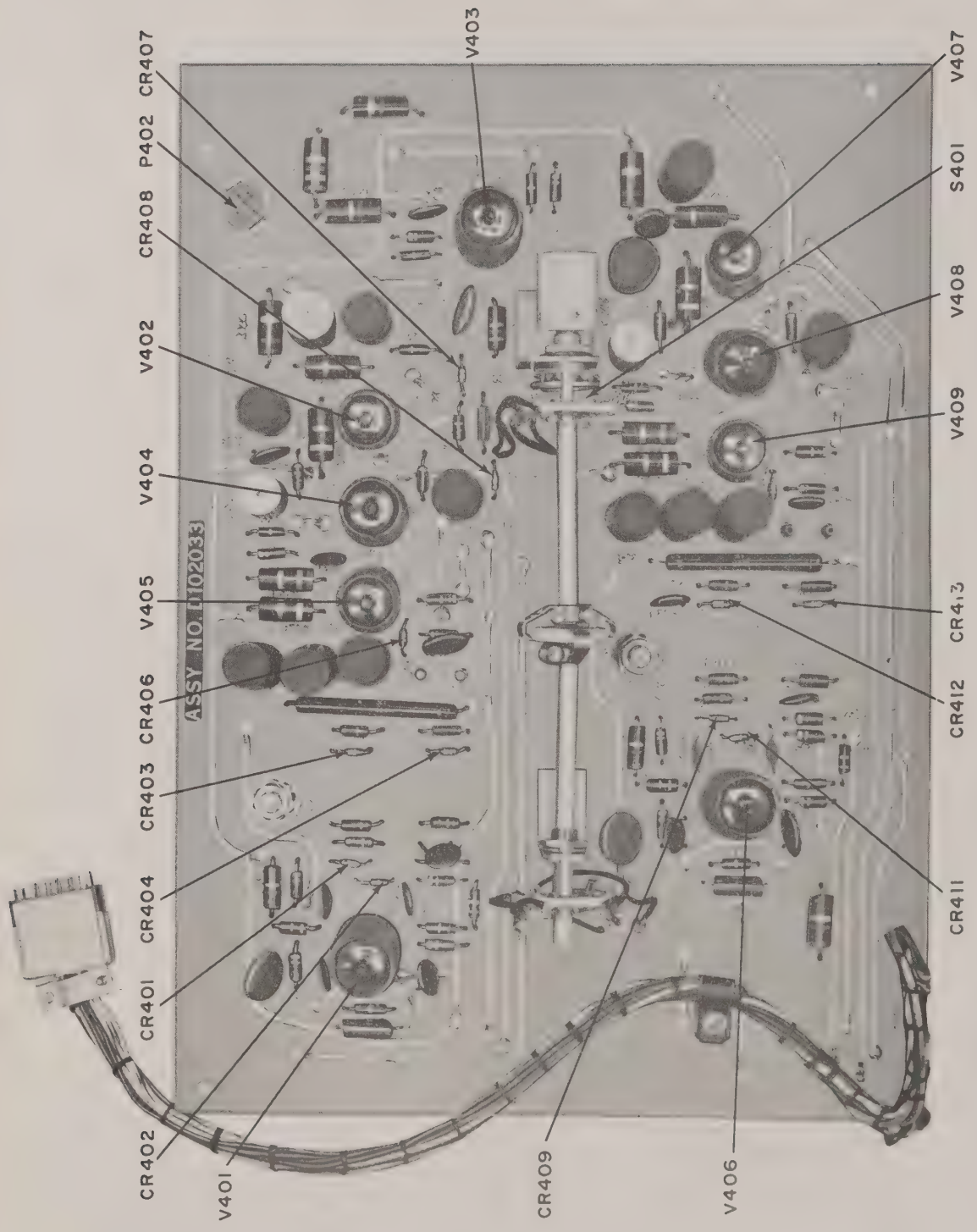


Figure 4-2. Input Board, Component Location (page 2 of 3)

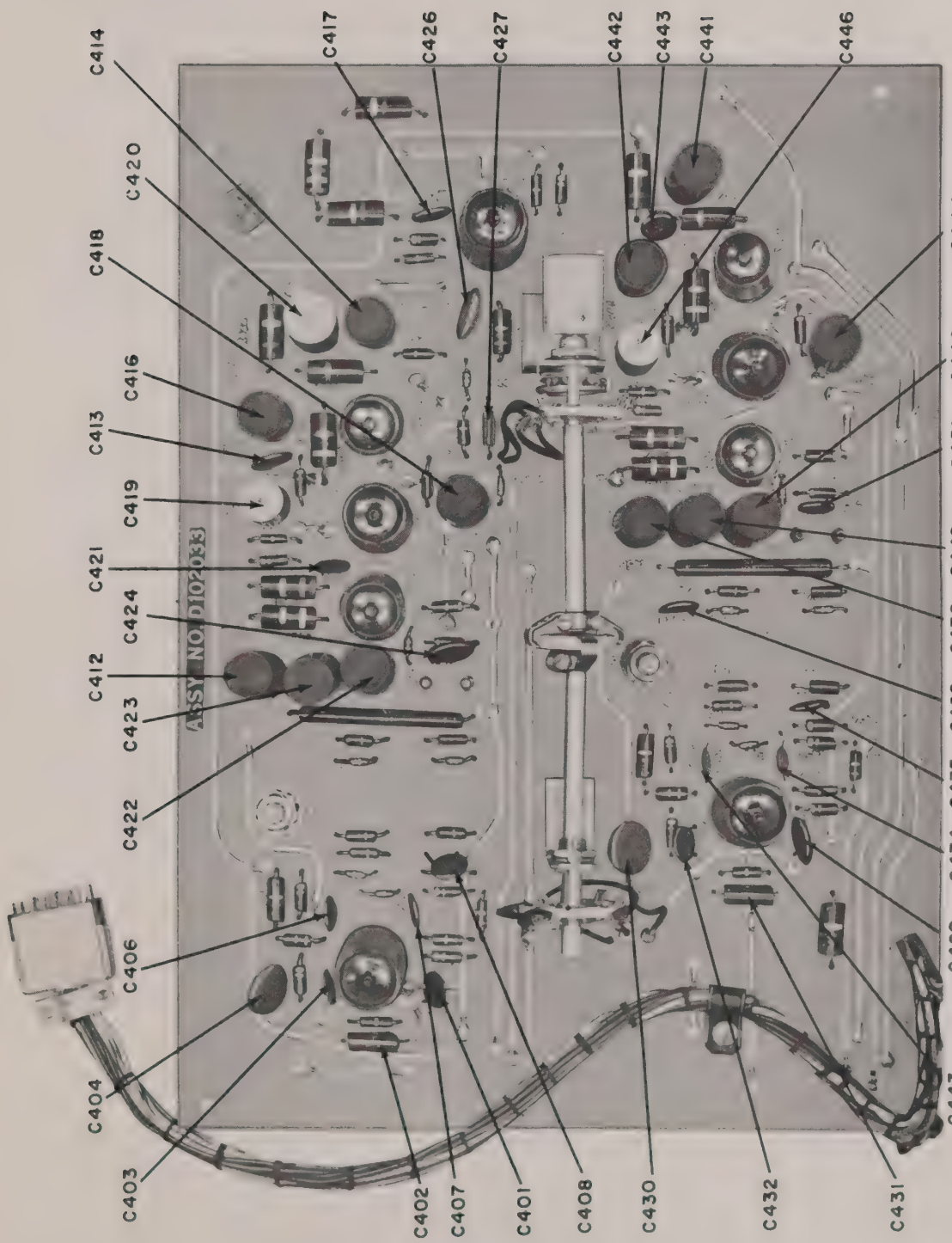


Figure 4-2. Input Board, Component Location (page 3 of 3)

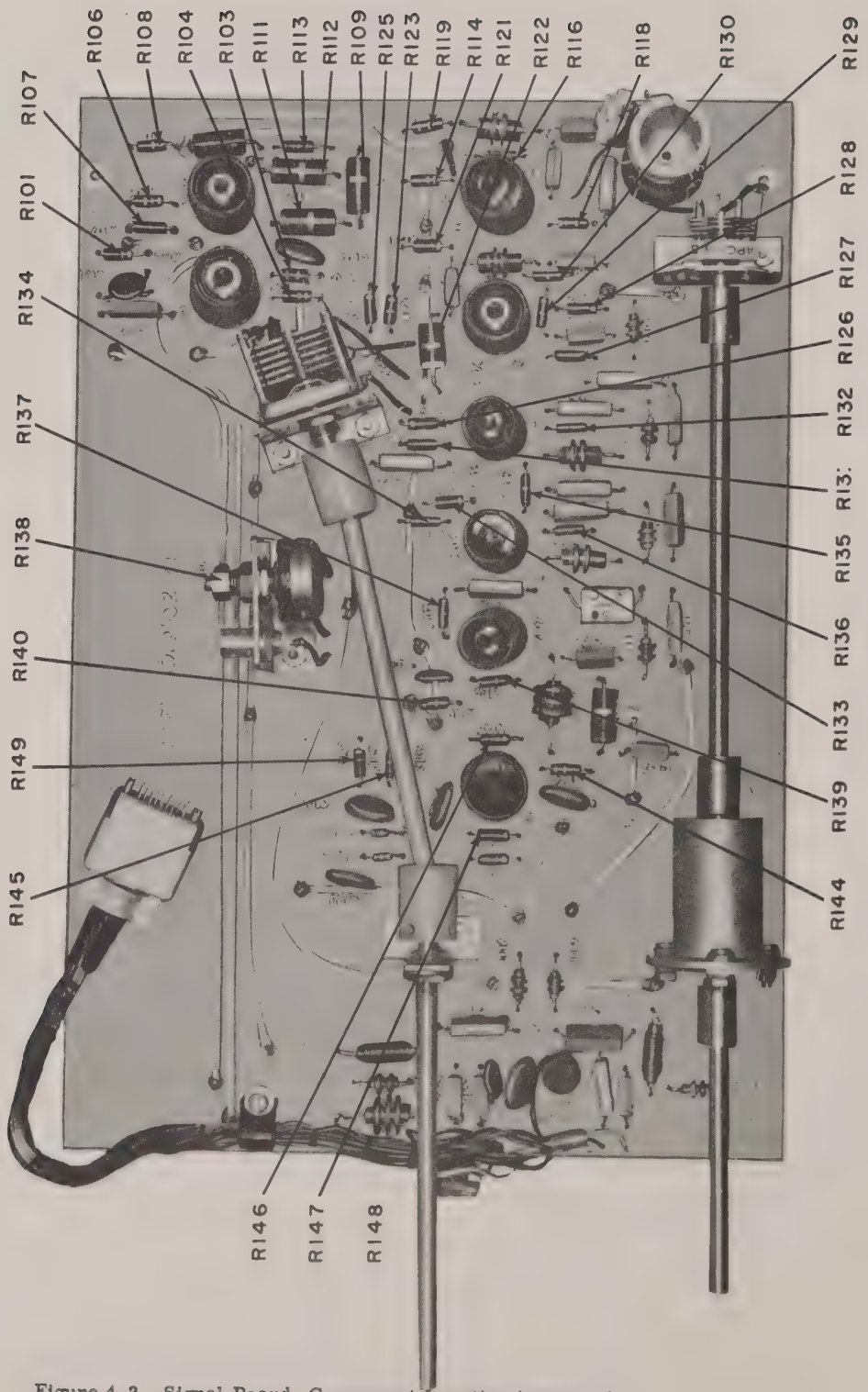


Figure 4-3. Signal Board, Component Location (page 1 of 2)

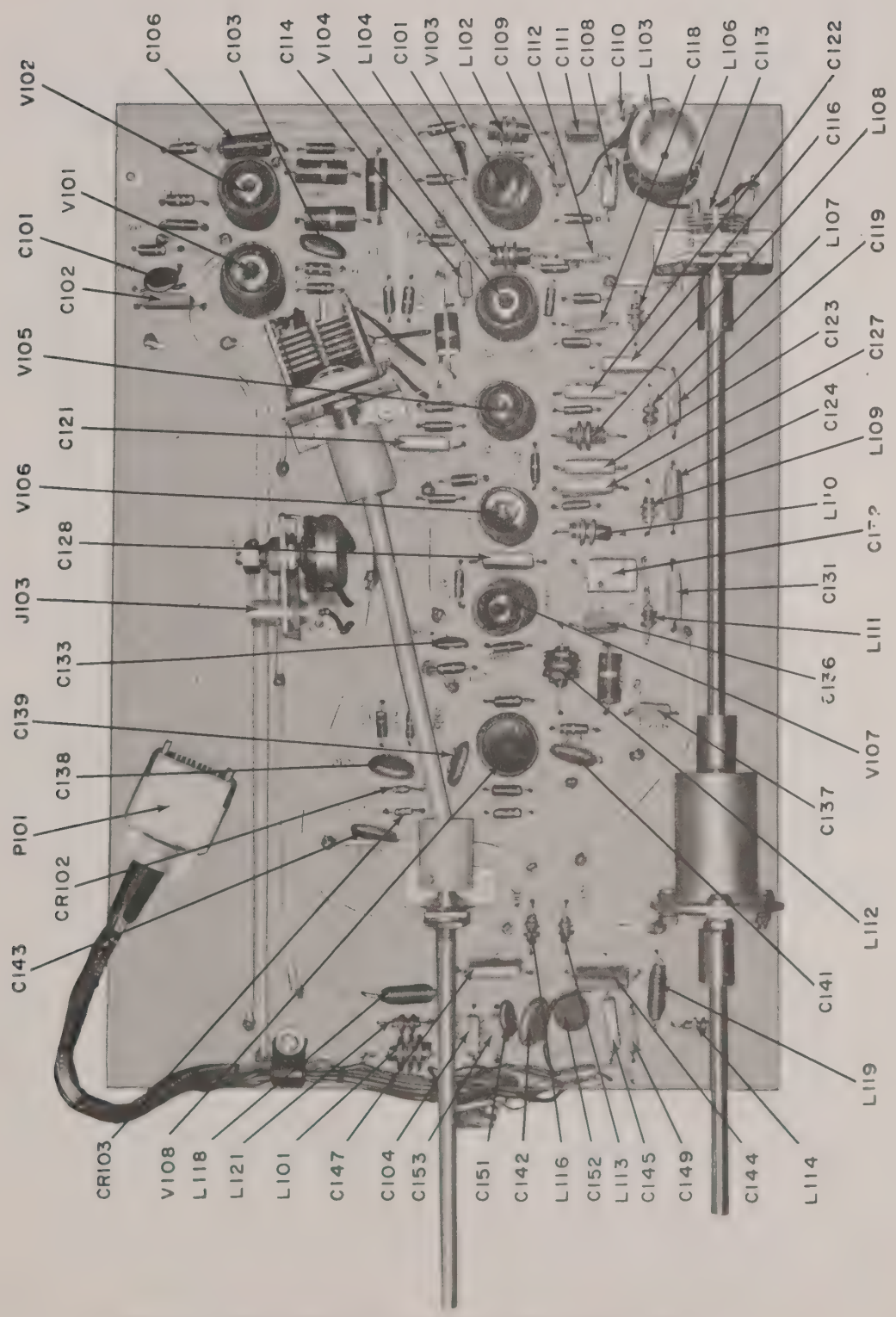


Figure 4-3. Signal Board, Component Location (page 2 of 2)

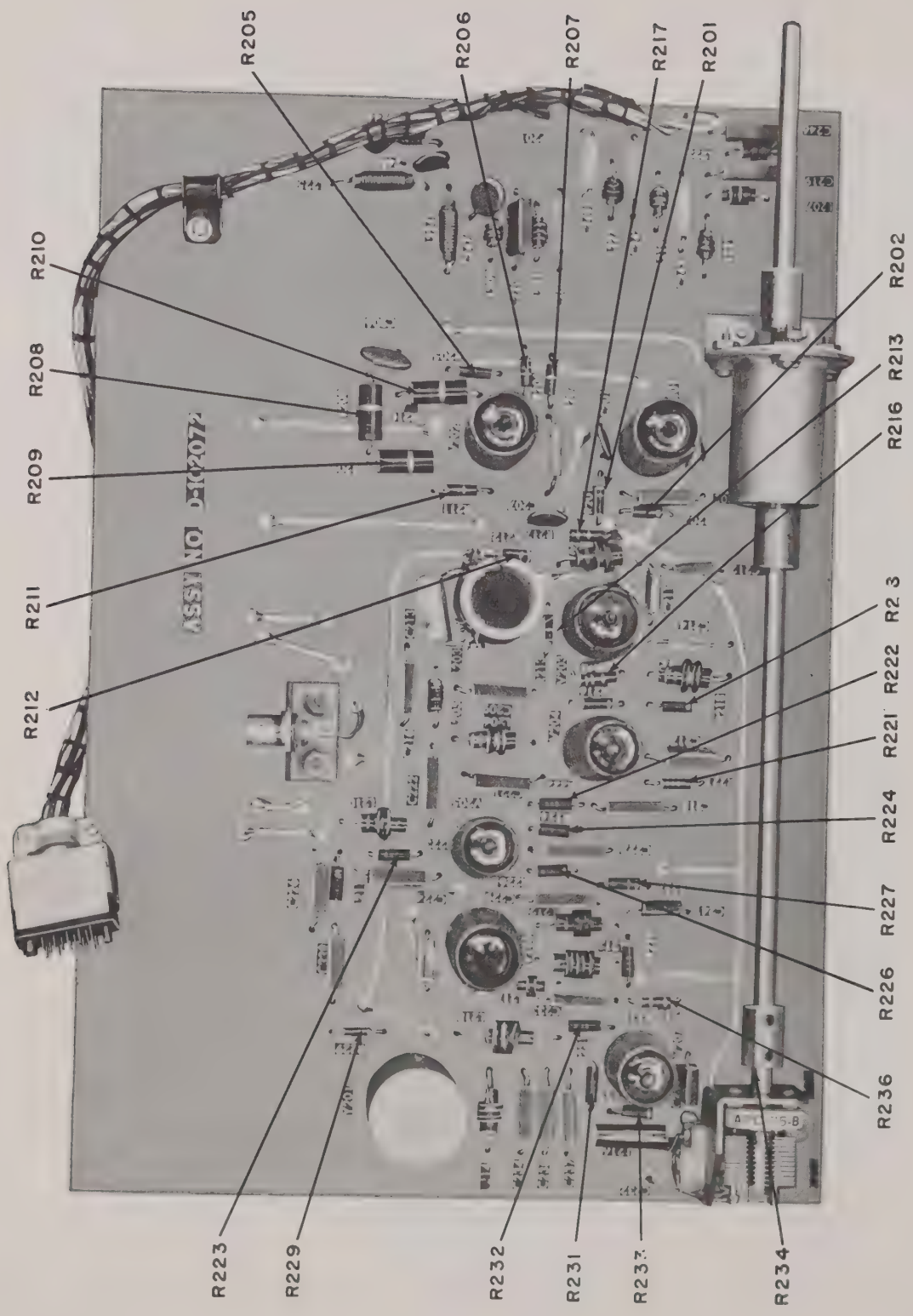


Figure 4-4. Reference Board, Component Location (page 1 of 3)

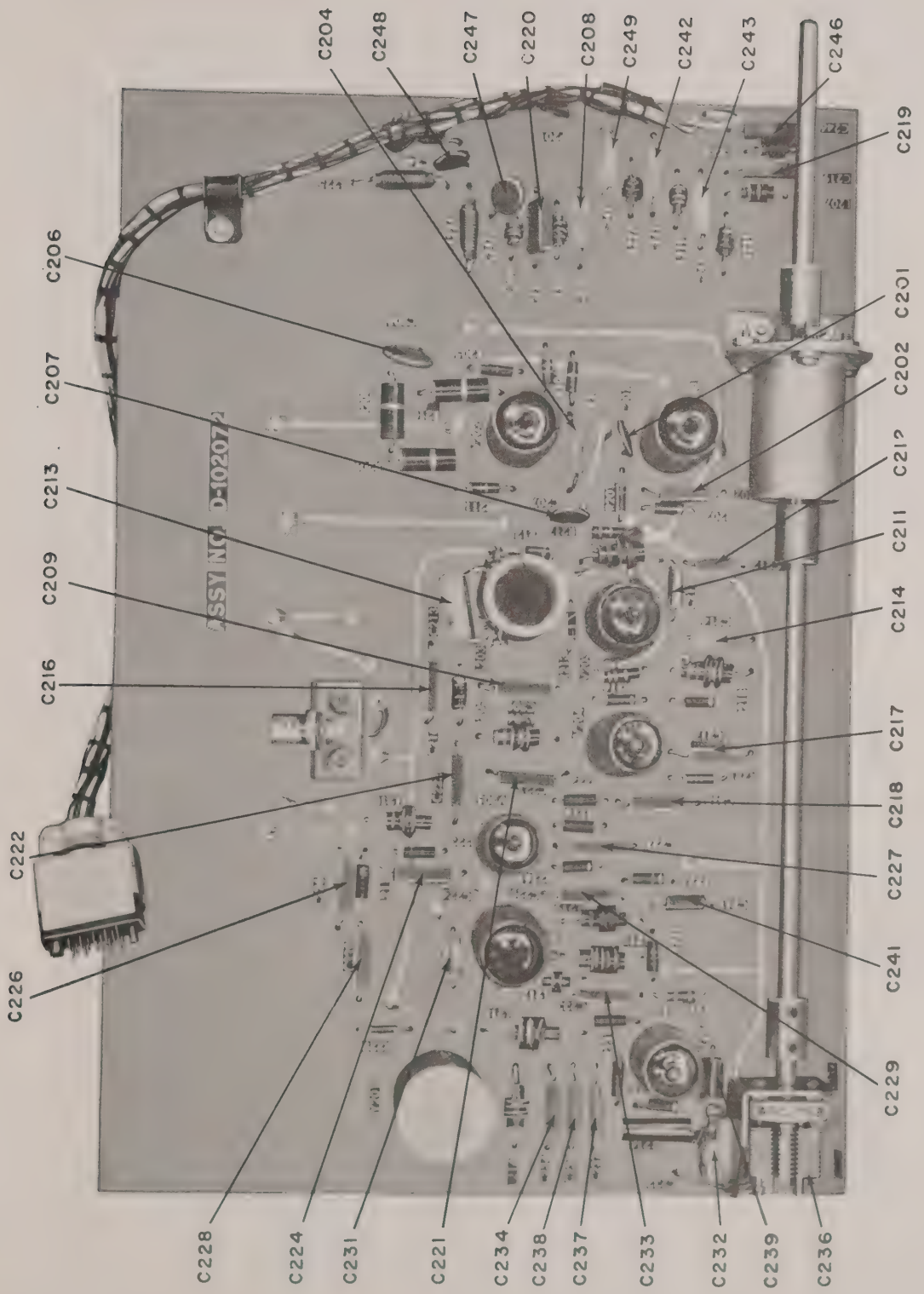


Figure 4-4. Reference Board, Component Location (page 2 of 3)

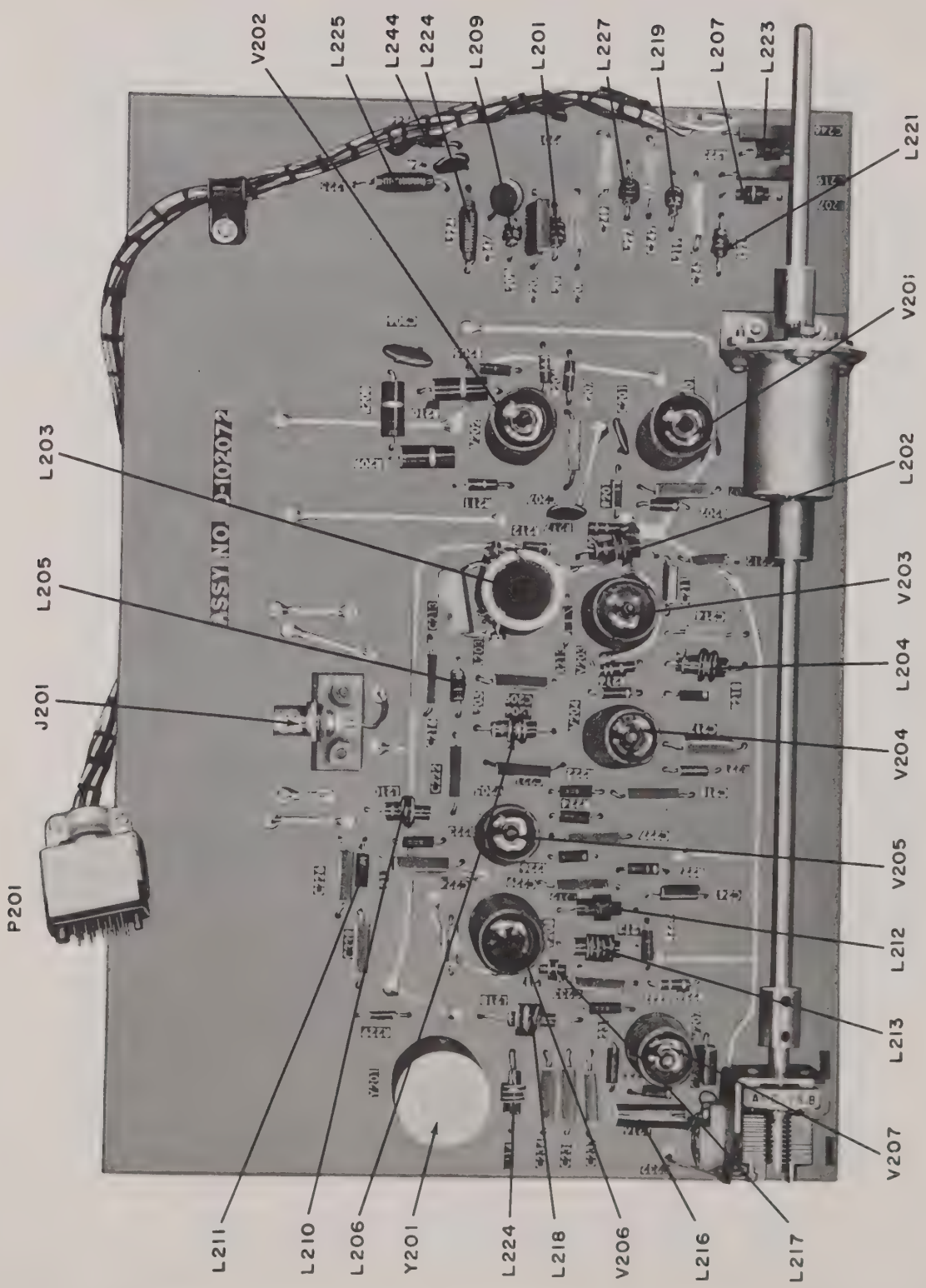


Figure 4–4. Reference Board, Component Location (page 3 of 3)

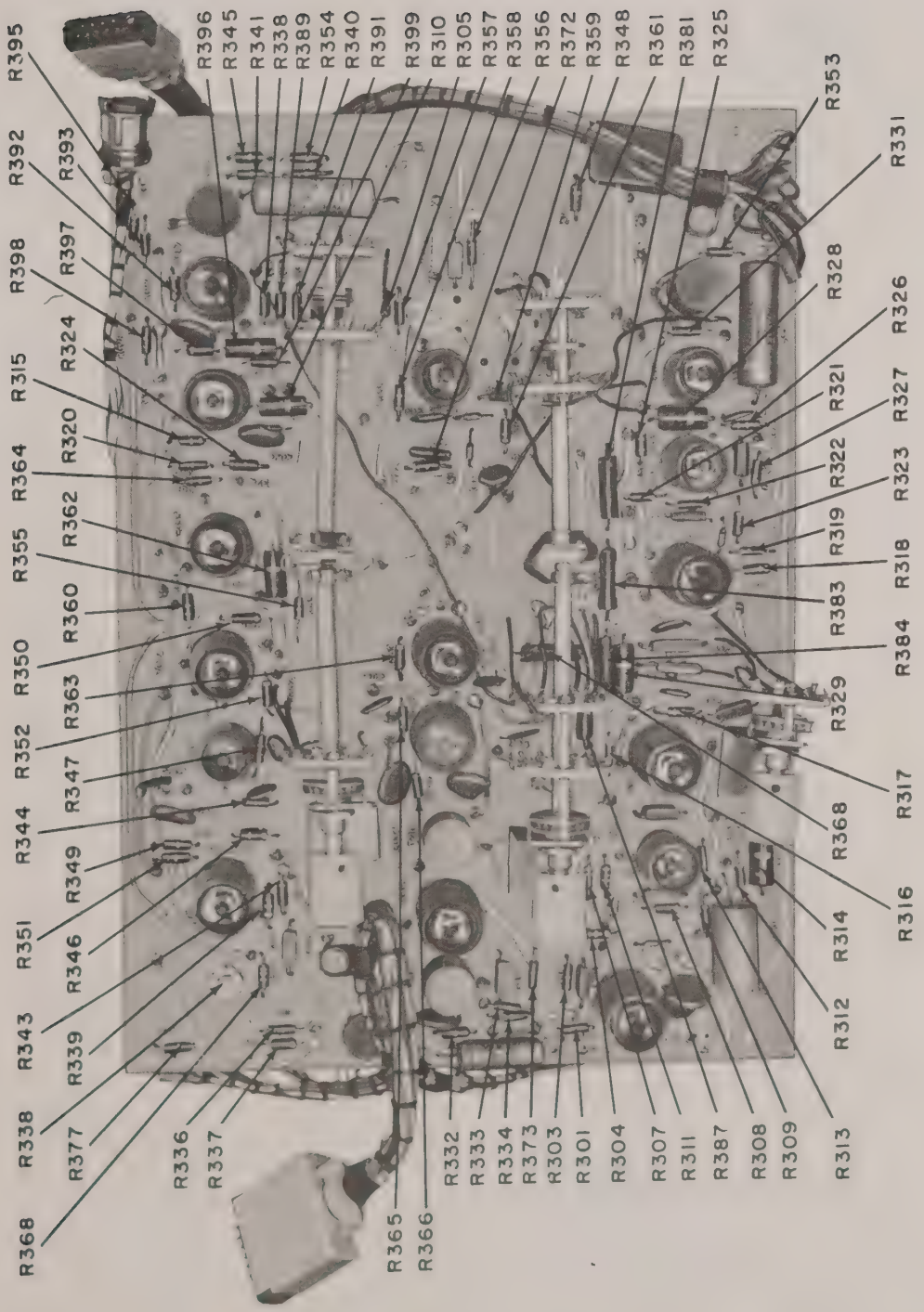


Figure 4-5. Output and Display Board, Component Location (page 1 of 2)

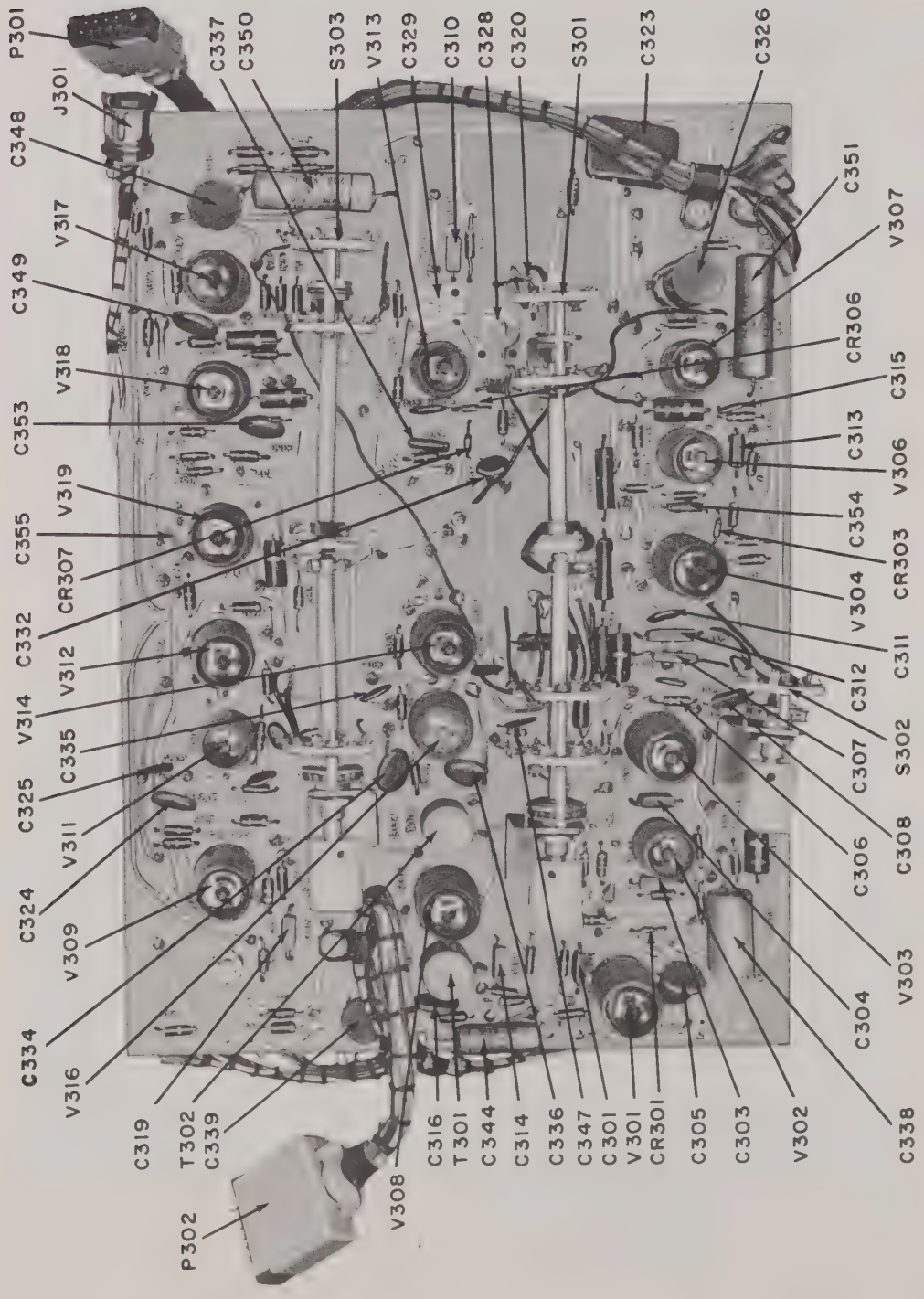


Figure 4-5. Output and Display Board, Component Location (page 2 of 2)

SECTION 5
SUPPLEMENTARY DATA

5-1. TUBE COMPLEMENT

a. Input Board. (See figures 4-2 and 6-1.)

Ref. Symbol	Tube Type	Function
V401	12AT7	Cathode Follower - Pulse Inverter.
V402	6AH6	Trigger Amplifier.
V403	12AT7	Cathode Follower - Cathode Follower.
V404	12AT7	Cathode Follower - Peak Detector.
V405	6AH6	Feedback Pulse Amplifier.
V406	12AT7	Cathode Follower - Pulse Inverter.
V407	6AH6	Trigger Amplifier.
V408	12AT7	Cathode Follower - Peak Detector.
V409	6AH6	Feedback Pulse Amplifier.

b. Signal and Reference Strip. (See figures 4-3, 4-4, and 6-2.)

V101	12AT7	Trigger Amplifier - Cathode Follower.
V102	12AT7	Gate Multivibrator.
V103	12AX7	Gating Cathode Follower - Gated Oscillator.
V104	12AT7	Phase Inverter.
V105	6AU6	5 Mc Signal Amplifier.
V106	6AN5	5 Mc Signal Driver.
V107	6BN6	Phase Detector.
V108	12AU7	Cathode Follower.
V201	12AT7	Trigger Amplifier.
V202	12AT7	Gate Multivibrator.
V203	12AX7	Gating Cathode Follower - Gated Oscillator.
V204	6AN5	5 Mc Reference Driver.
V205	6AN5	5 Mc Crystal Reference Driver.
V206	5751	5 Mc Crystal Reference Oscillator.
V207	6AK5	5 Mc Crystal Reference AFC Control.

c. Output and Display Section. (See figures 4-5 and 6-3.)

V301	12AT7	Trigger Amplifier - Cathode Follower.
V302	6AS6	Phantastron Delay Generator.
V303	12AT7	Phantastron Delay Generator - Cathode Follower.
V304	12AT7	Phantastron Delay Generator.
V306	6AS6	Phantastron Delay Generator.
V307	6AH6	Trigger Amplifier.
V308	12AT7	Blocking Oscillator.
V309	12AU7	Sweep Phantastron - Sync Amplifier.
V311	6AS6	Sweep Phantastron.
V312	12AX7	Blanking Amplifier.
V313	6AS6	Phantastron.
V314	12AU7	Hold Circuit - Cathode Follower.
V316	5755	Hold Circuit.
V317	12AX7	Vertical Preamplifier.
V318	12AU7	Vertical Amplifier.
V319	12AU7	Horizontal Amplifier.

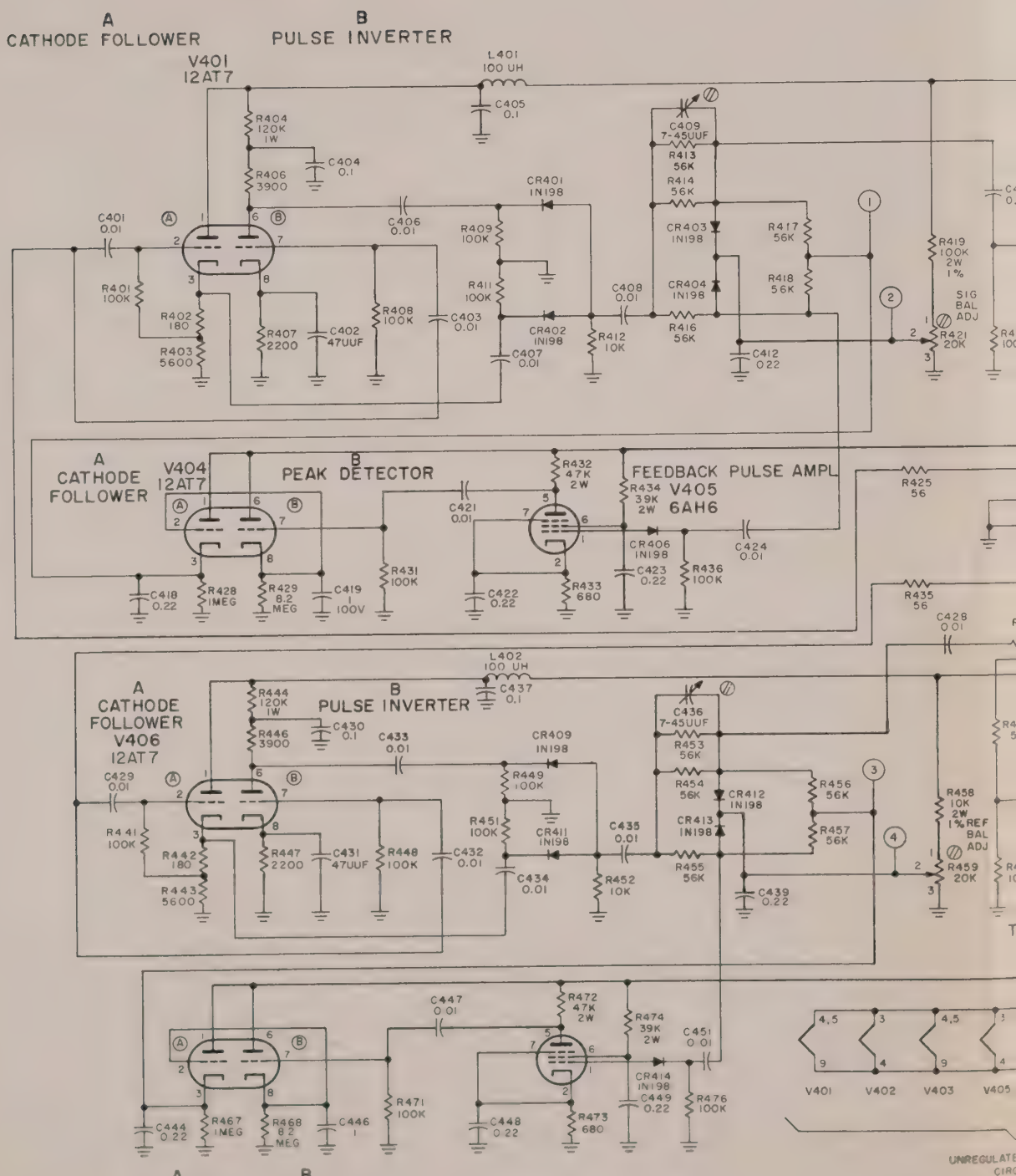
d. Power Supply. (See figures 4-1 and 6-4.)

Ref. Symbol	Tube Type	Function
V501	5R4GY	Positive Rectifier.
V502	6080	+250 V SERIES Control Tube.
V503	12AX7	+250 V Control Amplifier.
V504	0A2	+250 V Voltage Reference Tube.
V505	2X2A	High Voltage Rectifier.
V506	2C53	High Voltage Shunt Regulator.
V507	XVR-1500 or ANTON 424	High Voltage, Voltage Reference.
V508	6AQ5	+120 V SERIES Control Tube.
V509	12AX7	+120 V Control Amplifier.
V510	5651	+120 V Voltage Reference Tube.
V511	3WP1	CRT
V512	12AU7	Disturbance Frequency Cathode Follower.

5-2. TOTAL NUMBER OF TUBES PER TYPE

Qty	Type	Qty	Type
1	XVR1500	1	5651
1	0A2	1	5755
14	12AT7	1	5751
6	12AU7	1	6080
6	12AX7	5	6AH6
1	6AQ5	3	6AN5
1	2C53	4	6AS6
1	2X2A	1	6AU6
1	5R4GY	1	6BN6
1	6AK5	1	3WP1

Total number of tubes used: 52.


A
CATHODE FOLLOWER
B
PULSE INVERTER
V401
12AT7
L401
100 UH
C405
0.1
R404
120K
1W
C404
0.1
R406
3900
C409
7-45UUF
R413
56K
R414
56K
CR401
IN198
C401
0.01
C406
0.01
R409
100K
CR403
IN198
R417
56K
R419
100K
2W
1%
SIG
BAL
ADJ
R421
20K
R401
100K
R402
180
R403
5600
R407
2200
C402
47UUF
R408
100K
C403
0.01
R411
100K
CR402
IN198
C407
0.01
R412
10K
C408
0.01
CR404
IN198
R416
56K
R418
56K
C412
0.22
A
CATHODE
FOLLOWER
V404
12AT7
B
PEAK DETECTOR
R432
47K
2W
FEEDBACK PULSE AMPL
R434
39K
2W
V405
6AH6
R425
56
C421
0.01
CR406
IN198
C424
0.01
C423
0.22
R436
100K
C418
0.22
R428
1MEG
R429
8.2
MEG
C419
1
100V
R431
100K
C422
0.22
R433
680
R435
56
C428
0.01
L402
100 UH
A
CATHODE
FOLLOWER
V406
12AT7
B
PULSE INVERTER
C437
0.1
R444
120K
1W
C430
0.1
R446
3900
C433
0.01
CR409
IN198
C436
7-45UUF
R453
56K
C429
0.01
R449
100K
R454
56K
CR412
IN198
R456
56K
R458
10K
2W
1%
REF
BAL
ADJ
R459
20K
R441
100K
R442
180
R443
5600
R447
2200
C431
47UUF
R448
100K
C432
0.01
R451
100K
CR411
IN198
C435
0.01
CR413
IN198
R457
56K
C434
0.01
R452
10K
R455
56K
C439
0.22
C447
0.01
R472
47K
2W
R474
39K
2W
C451
0.01
CR414
IN198
C449
0.22
R476
100K
C444
0.22
R467
1MEG
R468
8.2
MEG
C446
1
R471
100K
C448
0.22
R473
680
V401
V402
V403
V405
A
CATHODE
FOLLOWER
B
PEAK
DETECTOR
V408
12AT7
FEEDBACK PULSE AMPL
V409
6AH6

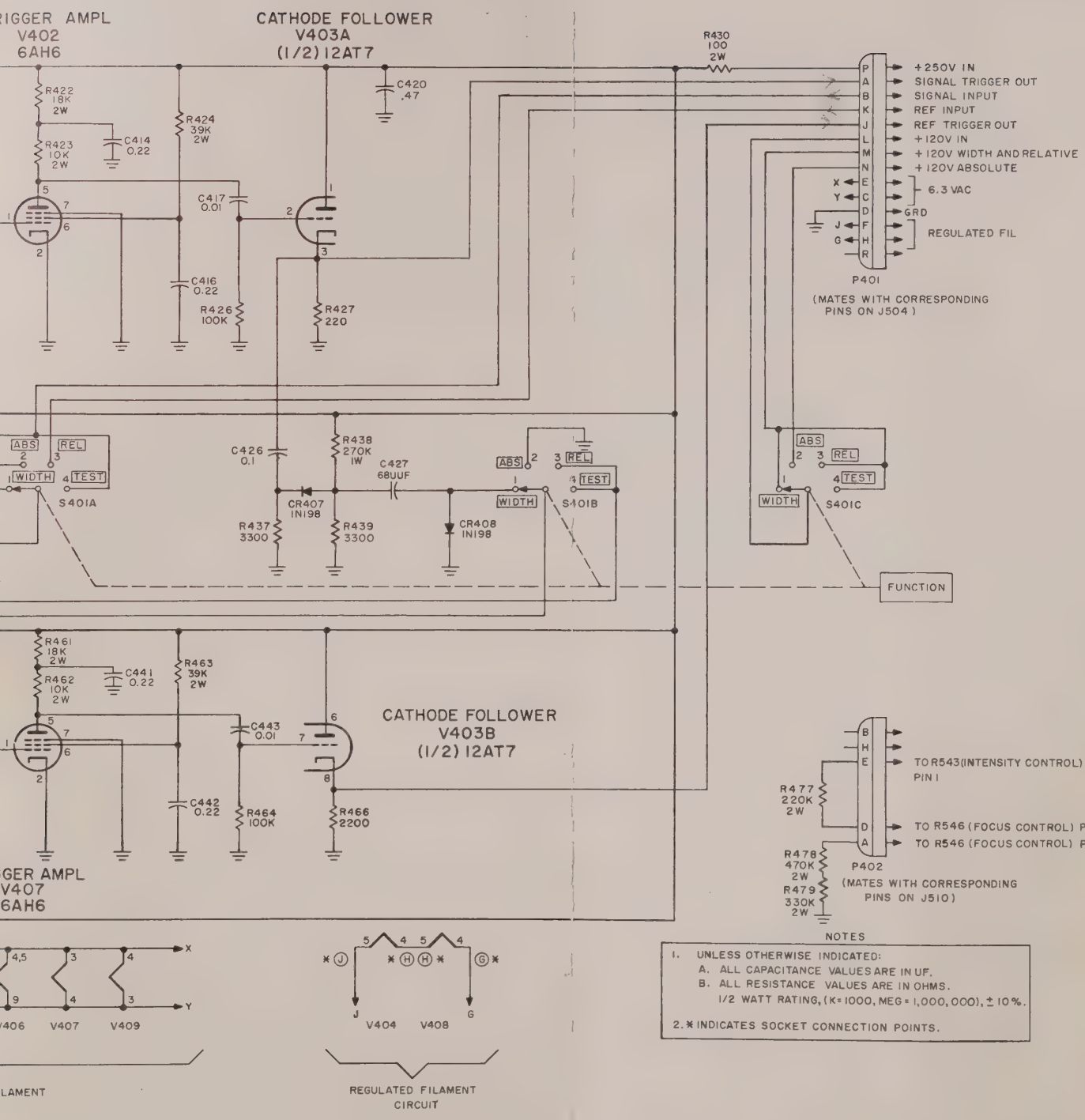
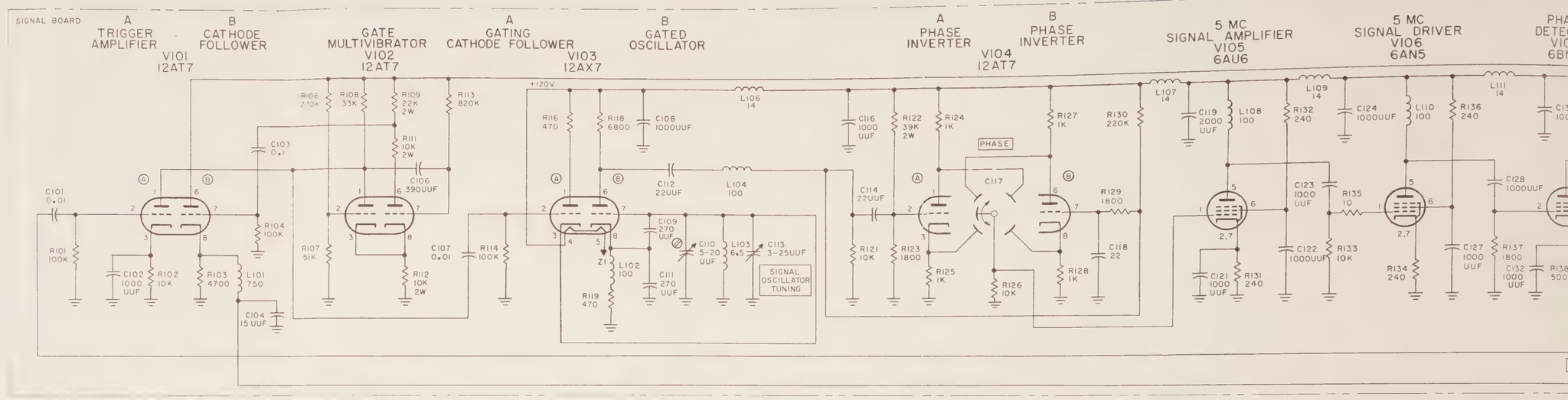
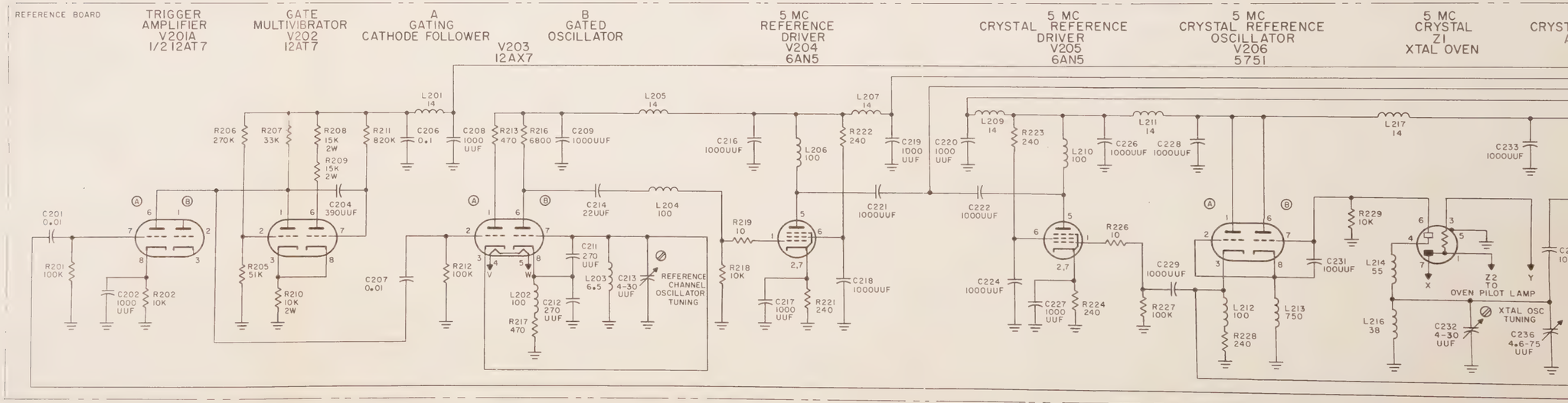
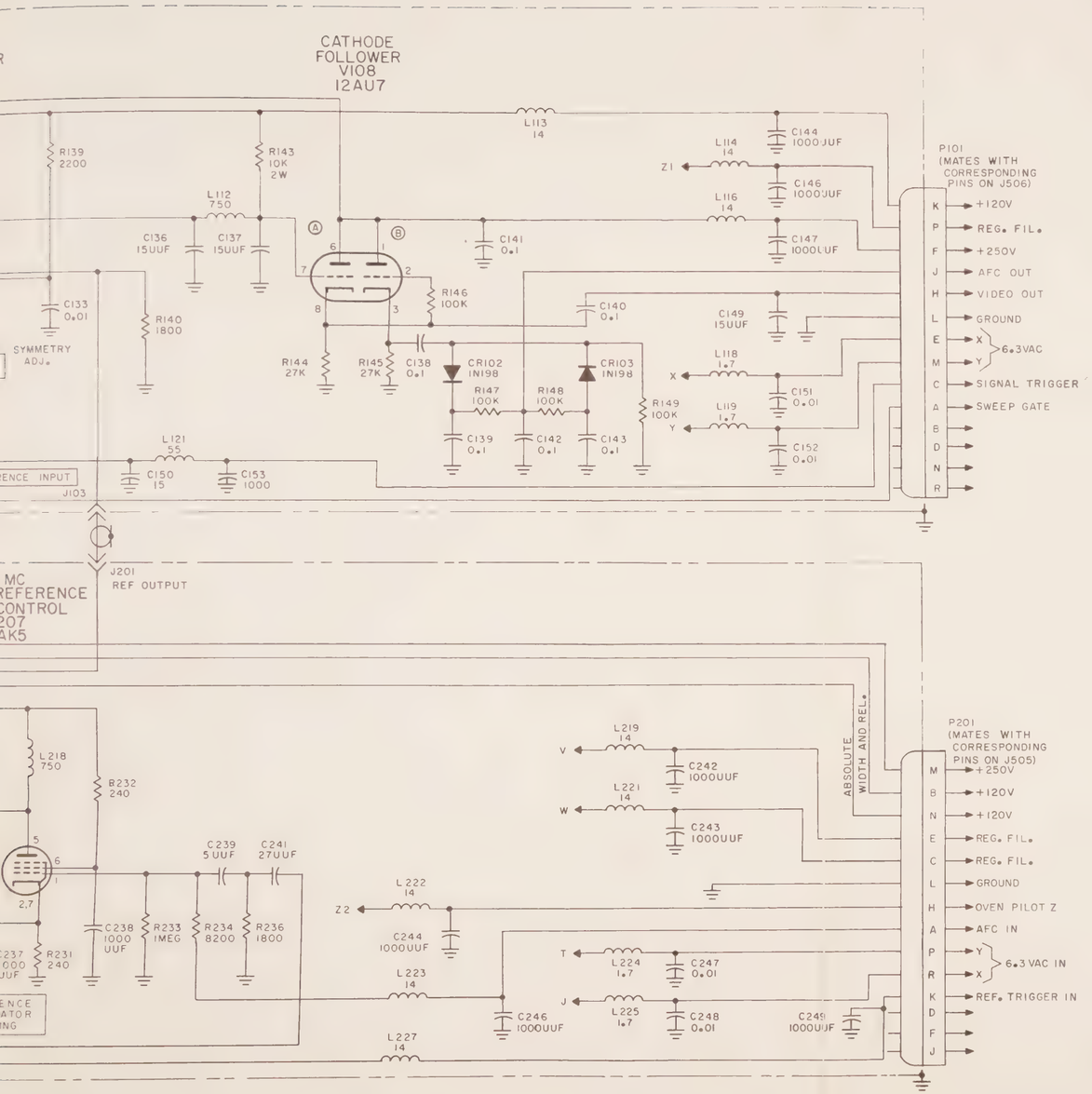


Figure 6-1. Pulse Jitter Tester, Input Board, Schematic Diagram


SIGNAL BOARD
A TRIGGER AMPLIFIER
B CATHODE FOLLOWER
V101 12AT7
GATE MULTIVIBRATOR V102 12AT7
A GATING CATHODE FOLLOWER
B GATED OSCILLATOR
V103 12AX7
A PHASE INVERTER
B PHASE INVERTER
V104 12AT7
5 MC SIGNAL AMPLIFIER V105 6AU6
5 MC SIGNAL DRIVER V106 6AN5
+120V
PHASE
SIGNAL OSCILLATOR TUNING


REFERENCE BOARD
TRIGGER AMPLIFIER V201A 1/2 12AT7
GATE MULTIVIBRATOR V202 12AT7
A GATING CATHODE FOLLOWER
B GATED OSCILLATOR
V203 12AX7
5 MC REFERENCE DRIVER V204 6AN5
5 MC CRYSTAL REFERENCE DRIVER V205 6AN5
5 MC CRYSTAL REFERENCE OSCILLATOR V206 5751
5 MC CRYSTAL Z1 XTAL OVEN
REFERENCE CHANNEL OSCILLATOR TUNING
Z2 TO OVEN PILOT LAMP
XTAL OSC TUNING

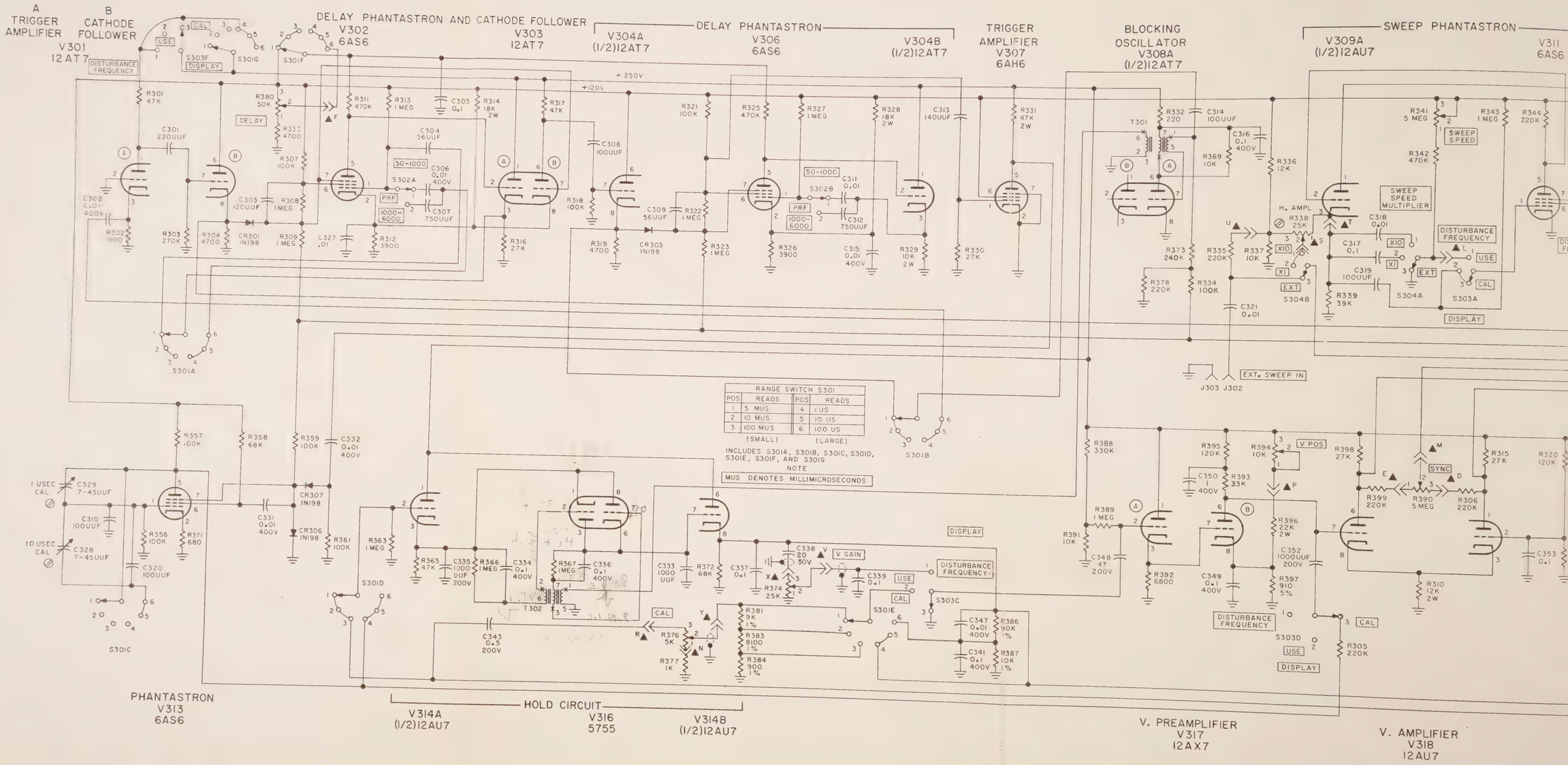
H112997

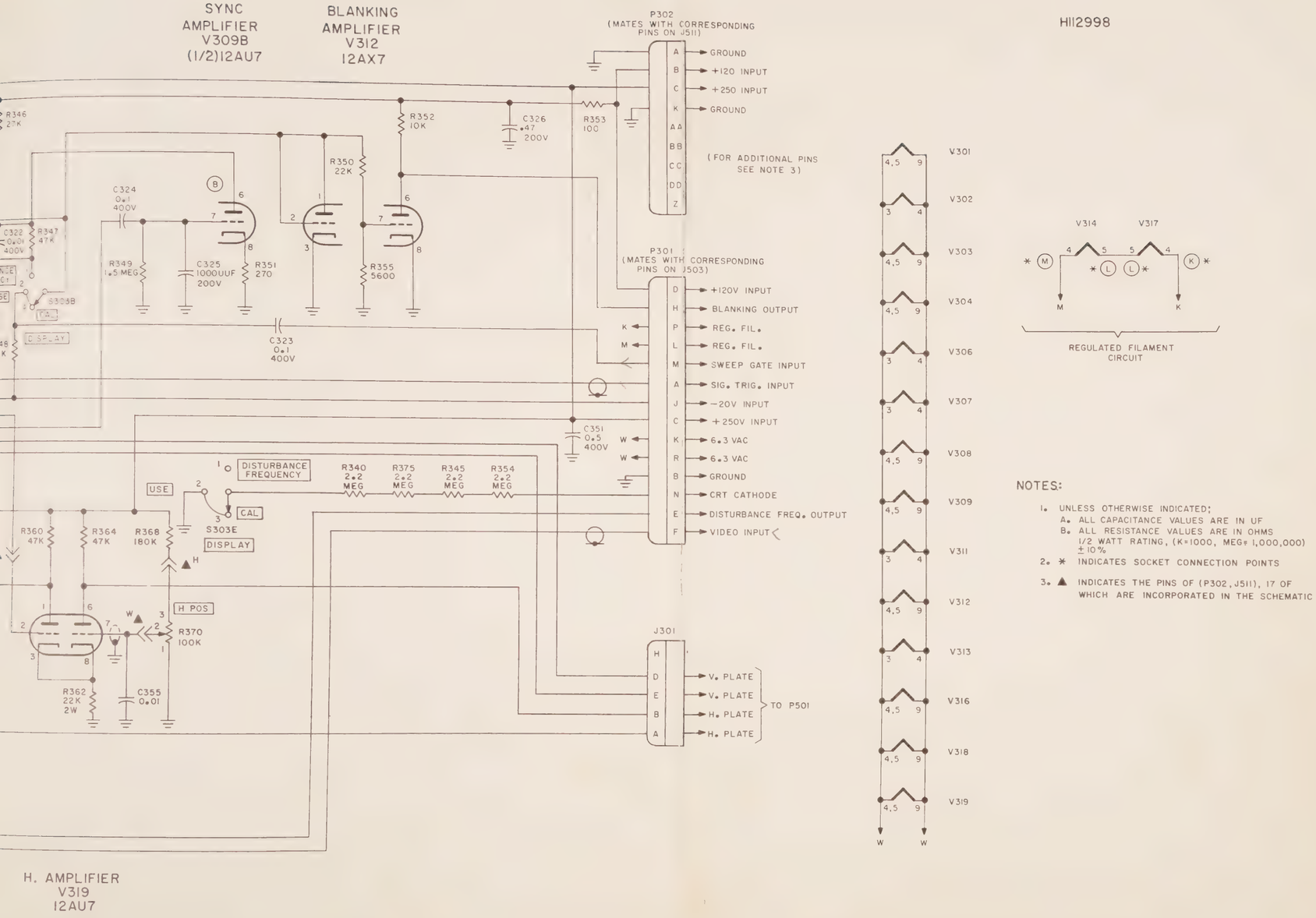


NOTES:

1. UNLESS OTHERWISE INDICATED
   A. ALL CAPACITANCE VALUES ARE IN UF.
   B. ALL RESISTANCE VALUES ARE IN OHMS, 1/2 WATT RATING ,(K=1000, MEG=1,000,000) ± 10%
   C. ALL COIL VALUES ARE IN UH.

Figure 6-2. Pulse Jitter Tester, Signal and Reference Strips, Schematic Diagrams


A TRIGGER AMPLIFIER
B CATHODE FOLLOWER
V301 12AT7
DISTURBANCE FREQUENCY
CAL
USE
DISPLAY
S303F
S301G
S301F
DELAY PHANTASTRON AND CATHODE FOLLOWER
V302 6AS6
V303 12AT7
DELAY PHANTASTRON
V304A (1/2)12AT7
V306 6AS6
V304B (1/2)12AT7
TRIGGER AMPLIFIER
V307 6AH6
BLOCKING OSCILLATOR
V308A (1/2)12AT7
SWEEP PHANTASTRON
V309A (1/2)12AU7
V311 6AS6
+250V
+120V
DELAY
PRF
50-1000
1000-6000
S302A
S302B
H. AMPL
SWEEP SPEED
SWEEP SPEED MULTIPLIER
DISTURBANCE FREQUENCY
EXT
S304B
S304A
S303A
EXT. SWEEP IN
J303 J302
S301A
S301B
RANGE SWITCH S301
POS | READS | POS | READS
1 | 5 MUS | 4 | 1 US
2 | 10 MUS | 5 | 10 US
3 | 100 MUS | 6 | 100 US
(SMALL) (LARGE)
INCLUDES S301A, S301B, S301C, S301D, S301E, S301F, AND S301G
NOTE
MUS DENOTES MILLIMICROSECONDS
1 USEC CAL
10 USEC CAL
S301C
S301D
S301E
S303C
S303D
V GAIN
V POS
SYNC
PHANTASTRON
V313 6AS6
HOLD CIRCUIT
V314A (1/2)12AU7
V316 5755
V314B (1/2)12AU7
V. PREAMPLIFIER
V317 12AX7
V. AMPLIFIER
V318 12AU7



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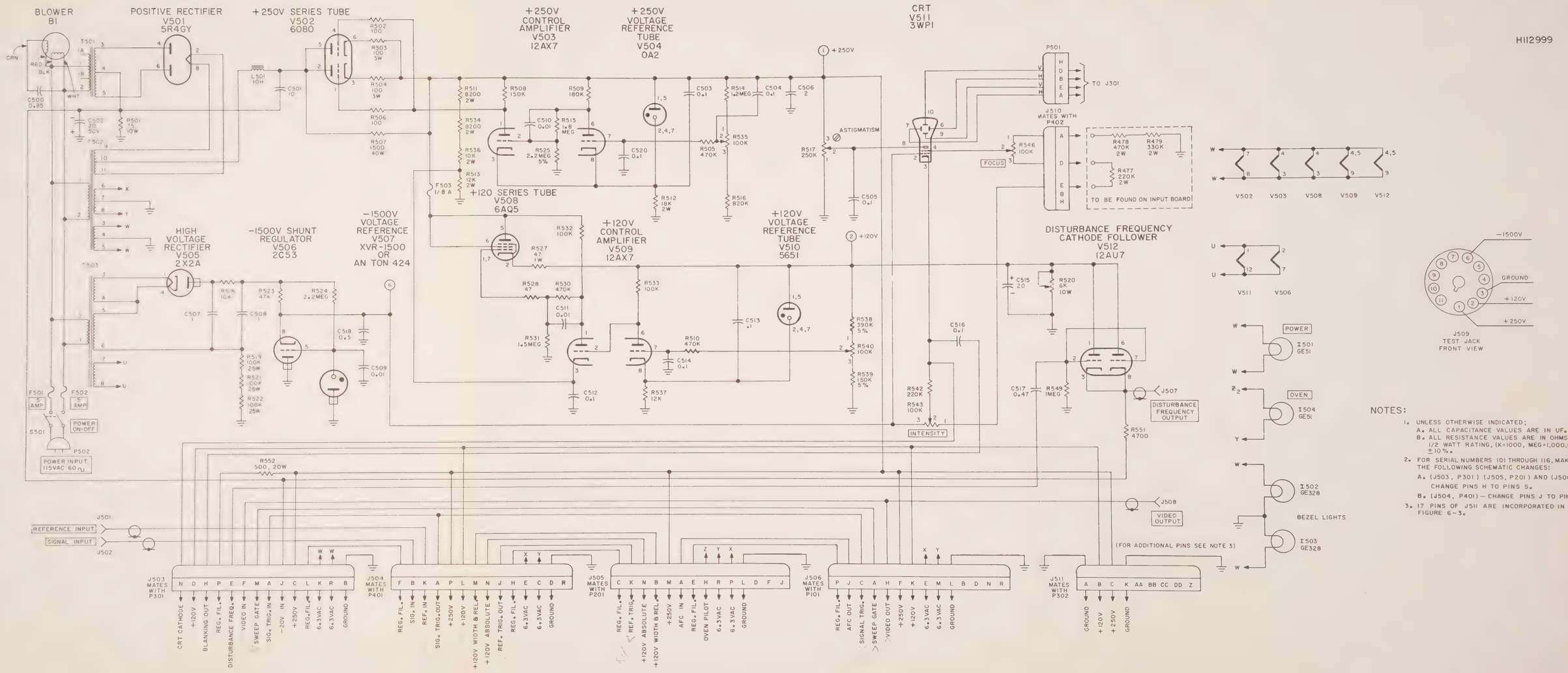
NOTES:

1. UNLESS OTHERWISE INDICATED;
   A. ALL CAPACITANCE VALUES ARE IN UF
   B. ALL RESISTANCE VALUES ARE IN OHMS 1/2 WATT RATING, (K=1000, MEG=1,000,000) ±10%
2. * INDICATES SOCKET CONNECTION POINTS
3. ▲ INDICATES THE PINS OF (P302, J511), 17 OF WHICH ARE INCORPORATED IN THE SCHEMATIC

Figure 6-3. Pulse Jitter Tester, Output and Display Section, Schematic Diagram



NOTES:

1. UNLESS OTHERWISE INDICATED;
   A. ALL CAPACITANCE VALUES ARE IN UF.
   B. ALL RESISTANCE VALUES ARE IN OHMS, 1/2 WATT RATING, (K=1000, MEG=1,000,000), ±10%.
2. FOR SERIAL NUMBERS 101 THROUGH 116, MAKE THE FOLLOWING SCHEMATIC CHANGES:
   A. (J503, P301) (J505, P201) AND (J506, P101) — CHANGE PINS H TO PINS S.
   B. (J504, P401) — CHANGE PINS J TO PINS S.
3. 17 PINS OF J511 ARE INCORPORATED IN FIGURE 6-3.

Figure 6-4. Pulse Jitter Tester, Power Supply, Schematic Diagram

SECTION VII
PARTS LIST

7-1. INTRODUCTION

This list describes all the electrical parts used in the PJ-1 Pulse Jitter Tester. The items are listed by schematic reference designation. When a common part is utilized the part number does not appear in the part number column. If a standard part is utilized the manufacturer's part number will appear in the description. When a part is available only from the Polarad Electronics Corporation, the part number is listed in the Polarad Part Number column.

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
B1	Blower; Fairchild part no. 1-836	
CR101	Not Used	
CR102, CR103	Semiconductor Device Diode; 1N198	
CR301	Same as CR102	
CR302	Not Used	
CR303	Same as CR102	
CR304, CR305	Not Used	
CR306, CR307	Same as CR102	
CR401 thru CR404	Same as CR102	
CR405	Not Used	
CR406 thru CR409	Same as CR102	
CR410	Not Used	
CR411 thru CR414	Same as CR102	
C101	Capacitor, Fixed, Ceramic Dielectric; 0.01 uf, 500 wvdc	
C102	Capacitor, Fixed, Mica Dielectric; 1000 uuf, ±10%, 300 wvdc	
C103	Capacitor, Fixed, Ceramic Dielectric; 0.1 uf, 500 wvdc	
C104	Capacitor, Fixed, Mica Dielectric; 15 uuf, ±10%, 300 wvdc	
C105	Not Used	
C106	Capacitor, Fixed, Mica Dielectric; 390 uuf, ±10%, 500 wvdc	
C107	Same as C101	
C108	Same as C102	
C109	Capacitor, Fixed, Mica Dielectric; 270 uuf, ±10%, 300 wvdc	
C110	Capacitor, Variable, Ceramic Dielectric; 5-20 uuf, 500 wvdc	
C111	Same as C109	
C112	Capacitor, Fixed, Mica Dielectric; 22 uuf, ±5%, 300 wvdc	
C113	Capacitor, Variable, Air Dielectric; 3-25 uuf, Hammarlund part no. APC-25-B	
C114	Same as C112	
C115	Not Used	
C116	Same as C102	
C117	Capacitor, Variable, Air Dielectric; 5-28 uuf	B102576
C118	Same as C112	
C119	Capacitor, Fixed, Mica Dielectric; 2,000 uuf, ±10%, 300 wvdc	
C120	Not Used	
C121	Same as C102	
C122 thru C124	Same as C102	
C125, C126	Not Used	
C127, C128	Same as C102	
C129, C130	Not Used	
C131, C132	Same as C102	
C133	Same as C101	

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
C134, C135	Not Used	
C136, C137	Same as C104	
C138 thru C143	Same as C103	
C144	Same as C102	
C145	Not Used	
C146, C147	Same as C102	
C148	Not Used	
C149, C150	Same as C104	
C151, C152	Same as C101	
C153	Same as C102	
C201	Same as C101	
C202	Capacitor, Fixed, Mica Dielectric; 1,000 uuf, ±10%, 500 wvdc	
C203	Not Used	
C204	Same as C106	
C205	Not Used	
C206	Same as C103	
C207	Same as C101	
C208, C209	Same as C202	
C210	Not Used	
C211, C212	Same as C109	
C213	Capacitor, Variable, Ceramic Dielectric; 4-30 uuf, 500 wvdc	
C214	Same as C112	
C215	Not Used	
C216 thru C222	Same as C202	
C223	Not Used	
C224	Same as C202	
C225	Not Used	
C226 thru C229	Same as C202	
C230	Not Used	
C231	Capacitor, Fixed, Mica Dielectric; 100 uuf, ±10%, 300 wvdc	
C232	Same as C213	
C233, C234	Same as C202	
C235	Not Used	
C236	Capacitor, Variable, Air Dielectric; 4.6-75 uuf, Hammarlund part no. APC-75-B	
C237, C238	Same as C202	
C239	Capacitor, Fixed, Mica Dielectric; 5 uuf, ±20%, 300 wvdc	
C240	Not Used	
C241	Capacitor, Fixed, Mica Dielectric; 27 uuf, ±10%, 300 wvdc	
C242 thru C244	Same as C202	
C245	Not Used	
C246	Same as C202	
C247, C248	Same as C101	
C249	Same as C202	
C301	Capacitor, Fixed, Mica Dielectric; 220 uuf, ±10%, 300 wvdc	
C302	Capacitor, Fixed, Ceramic Dielectric; 0.01 uf, 400 wvdc, Erie part no. 811-01	
C303	Capacitor, Fixed, Mica Dielectric; 120 uuf, ±10%, 300 wvdc	
C304	Capacitor, Fixed, Mica Dielectric; 56 uuf, ±10%, 300 wvdc	
C305	Same as C103	
C306	Same as C302	
C307	Capacitor, Fixed, Mica Dielectric; 750 uuf, ±10%, 300 wvdc	
C308	Same as C231	
C309	Same as C304	
C310	Same as C231	
C311	Same as C302	
C312	Same as C307	
C313	Capacitor, Fixed, Mica Dielectric; 140 uuf, ±10%, 300 wvdc	
C314	Same as C112	

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
C315	Same as C302	
C316, C317	Same as C103	
C318	Same as C302	
C319, C320	Same as C231	
C321, C322	Same as C302	
C323, C324	Same as C103	
C325	Capacitor, Fixed, Ceramic Dielectric; 1,000 uuf, 600 wvdc	
C326	Capacitor, Fixed, Paper Dielectric; 0.47 uf, 200 wvdc	
C327	Same as C302	
C328, C329	Capacitor, Variable, Ceramic Dielectric; 7–45 uuf, 500 wvdc	
C330	Not Used	
C331, C332	Same as C302	
C333	Same as C325	
C334	Same as C103	
C335	Same as C325	
C336, C337	Same as C103	
C338	Capacitor, Fixed, Electrolytic; 20 uf, 50 wvdc	
C339	Same as C103	
C340	Not Used	
C341	Same as C103	
C342	Not Used	
C343	Capacitor, Fixed, Paper Dielectric; 0.5 uf, 200 wvdc	
C344 thru C346	Not Used	
C347	Same as C302	
C348	Same as C326	
C349	Same as C103	
C350	Capacitor, Fixed, Plastic Dielectric; 1 uf, ±20%, 400 wvdc	
C351	Capacitor, Fixed, Paper Dielectric; 0.5 uf, ±20%, 400 wvdc	
C352	Same as C325	
C353	Same as C103	
C354	Not Used	
C355	Same as C302	
C401	Same as C101	
C402	Capacitor, Fixed, Mica Dielectric; 47 uuf, ±10%, 500 wvdc	
C403	Same as C101	
C404, C405	Same as C103	
C406 thru C408	Same as C101	
C409	Same as C328	
C410, C411	Not Used	
C412	Capacitor, Fixed, Paper Dielectric; 0.22 uf, 400 wvdc	
C413	Same as C101	
C414	Same as C412	
C415	Not Used	
C416	Same as C412	
C417	Same as C101	
C418	Same as C412	
C419	Capacitor, Fixed, Paper Dielectric; 1 uf, ±20%, 100 wvdc	
C420	Same as C326	
C421	Same as C101	
C422, C423	Same as C412	
C424	Same as C101	
C425	Not Used	
C426	Same as C103	
C427	Capacitor, Fixed, Mica Dielectric; 68 uuf, ±10%, 300 wvdc	
C428, C429	Same as C101	
C430	Same as C103	

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
C431	Same as C402	
C432 thru C435	Same as C101	
C436	Same as C328	
C437	Same as C103	
C438	Not Used	
C439	Same as C412	
C440	Not Used	
C441, C442	Same as C412	
C443	Same as C101	
C444	Same as C412	
C445	Not Used	
C446	Same as C419	
C447	Same as C101	
C448, C449	Same as C412	
C450	Not Used	
C451	Same as C101	
C500	Capacitor, Fixed; 0.85 uf, p/o B1	
C501	Capacitor, Fixed, Paper Dielectric; 10 uf, ±10%, 600 wvdc	
C502	Same as C338	
C503, C504	Capacitor, Fixed, Paper Dielectric; 0.1 uf, 400 wvdc	
C505	Same as C317	
C506	Capacitor, Fixed, Paper Dielectric; 2 uf, ±10%, 600 wvdc	
C507, C508	Capacitor, Fixed, Paper Dielectric; 1 uf, ±10%, 3000 wvdc	
C509	Capacitor, Fixed, Glass Dielectric; 0.01 uf, ±10%, 2000 wvdc	
C510	Same as C302	
C511	Same as C101	
C512 thru	Same as C503	
C514	Same as C503	
C515	Capacitor, Fixed, Electrolytic; 20 uf, 450 wvdc	
C516	Capacitor, Fixed, Glass Dielectric; 0.1 uf, ±10%, 2000 v	
C517	Capacitor, Fixed, Mylar Dielectric; 0.47 uf, ±10%, 400 wvdc	
C518	Capacitor, Fixed, Paper Dielectric; 0.5 uf, ±10%, 2000 wvdc	
C519	Not Used	
C520	Same as C503	
F501, F502	Fuse, Cartridge; 3AG	
F503	Fuse, Cartridge; 1/8 amps, 250 wvdc max	
I501	Lamp, Glow; NE51	
I502, I503	Lamp, Glow; G.E. 328	
I504	Same as I501	
J101, J102	Not Used	
J103	Connector, Receptacle, Electrical; UG-88/U	
J201	Same as J103	
J301	Connector, Receptacle, Electrical; Amphenol part no. 126-223	
J302	Connector, Receptacle, Electrical; Superior Electric part no. DF30RC	
J303	Connector, Receptacle, Electrical; Superior Electric part no. DF30BC	
J501, J502	Connector, Receptacle, Electrical; UG-909/U	
J503 thru J506	Connector, Receptacle, Electrical; 14 female contacts, Continental Connector Corp part no. 14-20S	
J507, J508	Same as J501	
J509	Connector, Receptacle, Electrical	B506721
J510	Same as J301	
J511	Connector, Receptacle, Electrical; 26 female contacts, Winchester Electric part no. MRE26S-G	

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
L101	Choke, RF; 750 uhy	A24510
L102	Choke, RF; 100 uhy	A24507
L103	Coil, RF; 6.5 uhy	A24506
L104	Same as L102	
L105	Not Used	
L106, L107	Choke, RF; 14 uhy	A24508
L108	Same as L102	
L109	Same as L106	
L110	Same as L102	
L111	Same as L106	
L112	Same as L101	
L113, L114	Same as L106	
L115	Not Used	
L116	Same as L106	
L117	Not Used	
L118, L119	Choke, RF; 1.7 uhy	A100366
L120	Not Used	
L121	Choke, RF; 55 uhy	A114365
L201	Same as L106	
L202	Same as L102	
L203	Same as L103	
L204	Same as L102	
L205	Same as L106	
L206	Same as L102	
L207	Same as L106	
L208	Not Used	
L209	Same as L106	
L210	Same as L102	
L211	Same as L106	
L212	Same as L102	
L213	Same as L101	
L214	Same as L121	
L215	Not Used	
L216	Choke, RF; 38 uhy	A100160
L217	Same as L106	
L218	Same as L101	
L219	Same as L106	
L220	Not Used	
L221 thru L223	Same as L106	
L224, L225	Same as L118	
L226	Not Used	
L227	Same as L106	
L401, L402	Same as L102	
L501	Choke; 10H	BP22853
P101	Connector, Plug, Electrical; 14 male contacts, Continental Connector part no. 14-20P	
P102	Connector, Plug, Electrical; UG-88/U	
P201	Same as P101	
P202	Same as P102	
P301	Same as P101	
P302	Connector, Plug, Electrical; 26 male connectors	A111495
P401	Same as P101	
P402	Connector, Plug, Electrical; 5 pins, Amphenol part no. 126-216	
P501	Same as P402	
P502	Connector, Plug, Electrical; Hubbell part no. 7486	
R101	Resistor, Fixed, Composition; 100,000 ohms, ±10%, 1/2 w	
R102	Resistor, Fixed, Composition; 10,000 ohms, ±10%, 1/2 w	
R103	Resistor, Fixed, Composition; 4700 ohms, ±10%, 1/2 w	

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
R104	Same as R101	
R105	Not Used	
R106	Resistor, Fixed, Composition; 270,000 ohms, ±10%, 1/2 w	
R107	Resistor, Fixed, Composition; 51,000 ohms ±10%, 1/2 w	
R108	Resistor, Fixed, Composition; 33,000 ohms, ±10%, 1/2 w	
R109	Resistor, Fixed, Composition; 22,000 ohms, ±10%, 2 w	
R110	Not Used	
R111, R112	Resistor, Fixed, Composition; 10,000 ohms, ±10%, 2 w	
R113	Resistor, Fixed, Composition; 820,000 ohms, ±5%, 1/2 w	
R114	Same as R101	
R115	Not Used	
R116	Resistor, Fixed, Composition; 470 ohms, ±10%, 1/2 w	
R117	Not Used	
R118	Resistor, Fixed, Composition; 6800 ohms, ±10%, 1/2 w	
R119	Same as R116	
R120	Not Used	
R121	Same as R102	
R122	Resistor, Fixed, Composition; 39,000 ohms, ±10%, 2 w	
R123	Resistor, Fixed, Composition; 1800 ohms, ±10%, 1/2 w	
R124, R125	Resistor, Fixed, Composition; 1,000 ohms, ±10%, 1/2 w	
R126	Same as R102	
R127, R128	Same as R124	
R129	Same as R123	
R130	Resistor, Fixed, Composition; 220,000 ohms, ±10%, 1/2 w	
R131, R132	Resistor, Fixed, Composition; 240 ohms, ±10%, 1/2 w	
R133	Same as R102	
R134	Same as R131	
R135	Resistor, Fixed, Composition; 10 ohms, ±10%, 1/2 w	
R136	Same as R131	
R137	Same as R123	
R138	Resistor, Variable, Composition; 500 ohms, ±10%, 2 w	
R139	Resistor, Fixed, Composition; 2,200 ohms, ±10%, 1/2 w	
R140	Same as R123	
R141, R142	Not Used	
R143	Same as R111	
R144, R145	Resistor, Fixed, Composition; 27,000 ohms, ±10%, 1/2 w	
R146 thru R149	Same as R101	
R201	Same as R101	
R202	Same as R102	
R203, R204	Not Used	
R205	Same as R107	
R206	Same as R106	
R207	Same as R108	
R208, R209	Resistor, Fixed, Composition; 15,000 ohms, ±10%, 2 w	
R210	Same as R111	
R211	Resistor, Fixed, Composition; 820,000 ohms, ±10%, 1/2 w	
R212	Same as R101	
R213	Same as R116	
R214, R215	Not Used	
R216	Same as R118	
R217	Same as R116	
R218	Same as R102	
R219	Same as R135	
R220	Not Used	
R221 thru R224	Resistor, Fixed, Composition; 240 ohms, ±5%, 1/2 w	
R225	Not Used	
R226	Same as R135	
R227	Same as R101	
R228	Same as R221	

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
R229	Same as R102	
R230	Not Used	
R231, R232	Same as R221	
R233	Resistor, Fixed, Composition; 1 megohm, ±10%, 1/2 w	
R234	Resistor, Fixed, Composition; 8,200 ohms, ±10%, 1/2 w	
R235	Not Used	
R236	Same as R123	
R301	Resistor, Fixed, Composition; 47,000 ohms, ±10%, 1/2 w	
R302	Same as R124	
R303	Same as R106	
R304	Same as R103	
R305, R306	Same as R130	
R307	Same as R101	
R308, R309	Same as R233	
R310	Resistor, Fixed, Composition; 12,000 ohms, ±10%, 2 w	
R311	Resistor, Fixed, Composition; 470,000 ohms, ±10%, 1/2 w	
R312	Resistor, Fixed, Composition; 3,900 ohms, ±10%, 1/2 w	
R313	Same as R233	
R314	Resistor, Fixed, Composition; 18,000 ohms, ±10%, 2 w	
R315, R316	Same as R144	
R317	Same as R301	
R318	Same as R101	
R319	Same as R103	
R320	Resistor, Fixed, Composition; 120,000 ohms, ±10%, 1/2 w	
R321	Same as R101	
R322, R323	Same as R233	
R324	Same as R301	
R325	Same as R311	
R326	Same as R312	
R327	Same as R233	
R328	Same as R314	
R329	Same as R111	
R330	Same as R144	
R331	Resistor, Fixed, Composition; 47,000 ohms, ±10%, 2 w	
R332	Resistor, Fixed, Composition; 220 ohms, ±10%, 1/2 w	
R333	Same as R103	
R334	Same as R101	
R335	Same as R130	
R336	Resistor, Fixed, Composition; 12,000 ohms, ±10%, 1/2 w	
R337	Same as R102	
R338	Resistor, Variable, Composition; 25,000 ohms, ±10%, 2 w	
R339	Resistor, Fixed, Composition; 39,000 ohms, ±10%, 1/2 w	
R340	Resistor, Fixed, Composition; 2.2 megohms, ±10%, 1/2 w	
R341	Resistor, Variable, Composition; 5 megohms, ±10%, 2 w	
R342	Same as R311	
R343	Same as R233	
R344	Same as R130	
R345	Same as R340	
R346	Same as R144	
R347	Same as R301	
R348	Same as R320	
R349	Resistor, Fixed, Composition; 1.5 megohms, ±10%, 1/2 w	
R350	Resistor, Fixed, Composition; 22,000 ohms, ±10%, 1/2 w	
R351	Resistor, Fixed, Composition; 270 ohms, ±10%, 1/2 w	
R352	Same as R102	
R353	Resistor, Fixed, Composition; 100 ohms, ±10%, 1/2 w	
R354	Same as R340	
R355	Resistor, Fixed, Composition; 5,600 ohms, ±10%, 1/2 w	
R356, R357	Same as R101	

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
R358	Resistor, Fixed, Composition; 68,000 ohms, ±10%, 1/2 w	
R359	Same as R101	
R360	Same as R301	
R361	Same as R101	
R362	Same as R109	
R363	Same as R233	
R364, R365	Same as R301	
R366, R367	Same as R233	
R368	Resistor, Fixed, Composition; 180,000 ohms, ±10%, 1/2 w	
R369	Same as R102	
R370	Resistor, Variable, Composition; 100,000 ohms, ±10%, 2 w	
R371	Resistor, Fixed, Composition; 680 ohms, ±10%, 1/2 w	
R372	Same as R358	
R373	Resistor, Fixed, Composition; 240,000 ohms, ±10%, 1/2 w	
R374	Resistor, Variable, Composition; 25,000 ohms, ±10%, 2 w	
R375	Same as R340	
R376	Resistor, Variable, Composition; 5,000 ohms, ±10%, 2 w	
R377	Same as R124	
R378	Same as R130	
R379	Not Used	
R380	Resistor, Variable, Composition; 50,000 ohms, ±5%, 2 w	
R381	Resistor, Fixed, Film; 9,000 ohms, ±1%, 1/2 w	
R382	Not Used	
R383	Resistor, Fixed, Film; 8,100 ohms, ±1%, 1 w	
R384	Resistor, Fixed, Film; 900 ohms, ±1%, 1/2 w	
R385	Not Used	
R386	Resistor, Fixed, Film; 90,000 ohms, ±1%, 1 w	
R387	Resistor, Fixed, Film; 10,000 ohms, ±1%, 1 w	
R388	Resistor, Fixed, Composition; 330,000 ohms, ±10%, 1/2 w	
R389	Same as R233	
R390	Same as R341	
R391	Same as R102	
R392	Same as R118	
R393	Same as R108	
R394	Resistor, Variable, Composition; 10,000 ohms, ±10%, 2 w	
R395	Same as R320	
R396	Same as R109	
R397	Resistor, Fixed, Composition; 910 ohms, ±5%, 1/2 w	
R398	Same as R144	
R399	Same as R130	
R401	Same as R101	
R402	Resistor, Fixed, Composition; 180 ohms, ±10%, 1/2 w	
R403	Same as R355	
R404	Resistor, Fixed, Composition; 120,000 ohms, ±10%, 1 w	
R405	Not Used	
R406	Same as R312	
R407	Resistor, Fixed, Composition; 2,200 ohms, ±10%, 1/2 w	
R408, R409	Same as R101	
R410	Not Used	
R411	Same as R101	
R412	Same as R102	
R413, R414	Resistor, Fixed, Composition; 56,000 ohms, ±5%, 1/2 w	
R415	Not Used	
R416 thru R418	Same as R413	
R419	Resistor, Fixed, Film; 100,000 ohms ±1%, 2 w	
R420	Same as R101	
R421	Resistor, Variable, Composition; 20,000 ohms, ±10%, 2 w	
R422	Same as R314	
R423	Same as R111	

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
R424	Same as R122	
R425	Resistor, Fixed, Composition; 56 ohms, ±10%, 1/2 w	
R426	Same as R419	
R427	Same as R332	
R428	Same as R233	
R429	Resistor, Fixed, Composition; 8.2 megohms, ±10%, 1/2 w	
R430	Resistor, Fixed, Composition; 100 ohms, ±10%, 2 w	
R431	Same as R101	
R432	Same as R331	
R433	Same as R371	
R434	Same as R122	
R435	Same as R425	
R436	Same as R101	
R437	Resistor, Fixed, Composition; 3,300 ohms, ±10%, 1/2 w	
R438	Resistor, Fixed, Composition; 270,000 ohms, ±10%, 1 w	
R439	Same as R437	
R440	Same as R425	
R441	Same as R101	
R442	Same as R402	
R443	Same as R355	
R444	Same as R404	
R445	Same as R425	
R446	Same as R312	
R447	Same as R407	
R448, R449	Same as R101	
R450	Not Used	
R451	Same as R101	
R452	Same as R102	
R453 thru R457	Same as R413	
R458	Same as R419	
R459	Same as R421	
R460	Same as R101	
R461	Same as R314	
R462	Same as R111	
R463	Same as R122	
R464	Same as R101	
R465	Not Used	
R466	Same as R407	
R467	Same as R233	
R468	Same as R429	
R469, R470	Not Used	
R471	Same as R101	
R472	Same as R331	
R473	Same as R371	
R474	Same as R122	
R475	Not Used	
R476	Same as R101	
R477	Resistor, Fixed, Composition; 220,000 ohms, ±10%, 2 w	
R478	Resistor, Fixed, Composition; 470,000 ohms, ±10%, 2 w	
R479	Resistor, Fixed, Composition; 330,000 ohms, ±10%, 2 w	
R501	Resistor, Fixed, Wirewound; 75 ohms, ±5%, 10 w	
R502	Same as R353	
R503, R504	Resistor, Fixed, Composition; 100 ohms, ±10%, 3 w	
R505	Same as R311	
R506	Same as R353	
R507	Resistor, Fixed, Wirewound; 1,500 ohms, ±5%, 40 w	
R508	Resistor, Fixed, Composition; 150,000 ohms, ±10%, 1/2 w	
R509	Same as R368	
R510	Same as R311	

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
R511	Resistor, Fixed, Composition; 8,200 ohms, ±10%, 2 w	
R512	Same as R314	
R513	Same as R310	
R514	Resistor, Fixed, Composition; 1.2 megohms, ±10%, 1/2 w	
R515	Resistor, Fixed, Composition; 1.8 megohms, ±5%, 1/2 w	
R516	Resistor, Fixed, Composition; 750,000 ohms, ±5%, 1/2 w	
R517	Resistor, Variable, Composition; 250,000 ohms, ±10%, 2 w	
R518	Same as R102	
R519	Resistor, Fixed, Wirewound; 100,000 ohms, ±10%, 25 w	
R520	Resistor, Variable, Wirewound; 6,000 ohms, ±10%, 10 w	
R521, R522	Same as R519	
R523	Same as R331	
R524	Same as R340	
R525	Resistor, Fixed, Composition; 2.2 megohms, ±5%, 1/2 w	
R526	Not Used	
R527	Resistor, Fixed, Composition; 47 ohms, ±10%, 1 w	
R528	Resistor, Fixed, Composition; 47 ohms, ±10%, 1/2 w	
R529	Not Used	
R530	Same as R311	
R531	Same as R349	
R532, R533	Same as R101	
R534	Same as R511	
R535	Resistor, Variable, Composition; 100,000 ohms, ±10%, 2 w, 1/8 in. dia slotted shaft 7/8 in. lg	
R536	Same as R111	
R537	Same as R336	
R538	Resistor, Fixed, Composition; 390,000 ohms, ±5%, 1/2 w	
R539	Resistor, Fixed, Composition; 150,000 ohms, ±5%, 1/2 w	
R540	Same as R535	
R541	Not Used	
R542	Same as R130	
R543	Resistor, Variable, Composition; 100,000 ohms, ±10%, 2 w, 1/8 in. dia slotted shaft 1/2 in. lg	
R544, R545	Not Used	
R546	Same as R543	
R547, R548	Not Used	
R549	Same as R233	
R550	Not Used	
R551	Same as R103	
R552	Resistor, Fixed, Wirewound; 500 ohms, ±5%, 20 w	
S301	Switch, Rotary; 2 pole, 6 position	B111493
S302	Switch, Rotary; 3 pole, 2 position	A111494
S303	Switch, Rotary; 3 pole, 3 position	B111492
S304	Switch, Rotary; 2 pole, 2-6 position	A123860
S401	Switch, Rotary; 3 pole, 4 position	B102597
S501	Switch, Toggle; dpdt	
T301, T302	Transformer, Pulse; Polyphase part no. P111K841	
T501	Transformer, Power	B27459
T502	Transformer, Filament	B22852
T503	Transformer, Power	B27458
V101, V102	Electron Tube; 12AT7	
V103	Electron Tube; 12AX7	
V104	Same as V101	
V105	Electron Tube; 6AU6	
V106	Electron Tube; 6AN5	

REFERENCE DESIGNATION	DESCRIPTION	POLARAD PART NO.
V107	Electron Tube; 6BN6	
V108	Electron Tube; 12AU7	
V201, V202	Same as V101	
V203	Same as V103	
V204, V205	Same as V106	
V206	Electron Tube; 5751	
V207	Electron Tube; 6AK5	
V301	Same as V101	
V302	Electron Tube; 6AS6	
V303, V304	Same as V101	
V305	Not Used	
V306	Same as V302	
V307	Electron Tube; 6AH6	
V308	Same as V101	
V309	Same as V108	
V310	Not Used	
V311	Same as V302	
V312	Same as V103	
V313	Same as V302	
V314	Same as V108	
V315	Not Used	
V316	Electron Tube; 5755	
V317	Same as V103	
V318, V319	Same as V108	
V401	Same as V101	
V402	Same as V307	
V403, V404	Same as V101	
V405	Same as V307	
V406	Same as V101	
V407	Same as V307	
V408	Same as V101	
V409	Same as V307	
V501	Electron Tube; 5R4GY	
V502	Electron Tube; 6080	
V503	Same as V103	
V504	Electron Tube; 0A2	
V505	Electron Tube; 2X2A	
V506	Electron Tube; 2C53	
V507	Electron Tube; Victoreen part no. XVR1500	
V508	Electron Tube; 6AQ5	
V509	Same as V103	
V510	Electron Tube; 5651	
V511	Electron Tube; 3WP1	
V512	Same as V108	
	ACCESSORIES	
W101	Cable Assembly, Video	B12553
W102	Cable Assembly, Test; 5 pin	B113355
W103	Cable Assembly, Test, 14 pin	B113356
W104	Cable Assembly, Test; 26 pin	B113357
W105	Cable Assembly, Power	B111144
Z1	Crystal Assembly; c/o 5 mc quartz crystal CR-28/U and a MC-6/U holder	